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PLANTERS' RECORD

VOL. XXXV

A quarterly paper devoted to the sugar interests of Hawaii, and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

JANUARY TO DECEMBER

THE HAWAIIAN PLANTERS' RECORD

VOL. XXXV

ORGAN OF THE EXPERIMENT STATION OF THE
HAWAIIAN SUGAR PLANTERS' ASSOCIATION

HONOLULU
1931

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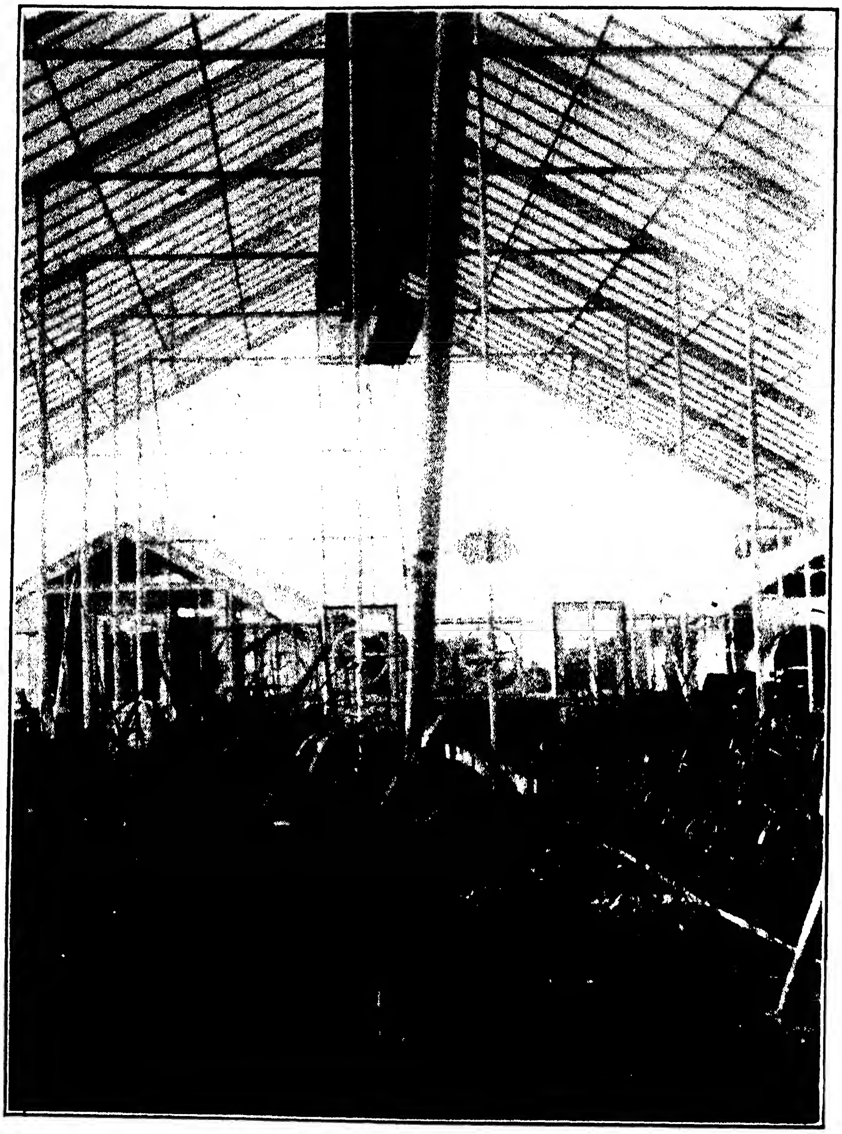
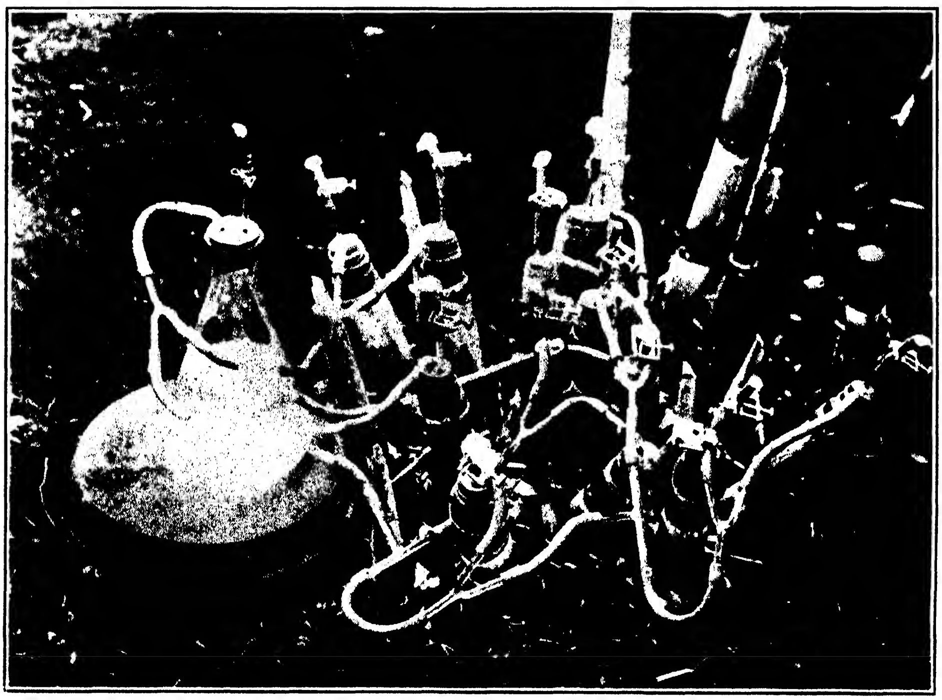
ILLUSTRATIONS APPEARING ON THE COVERS OF VOLUME XXXV

January



Seedlings from tassels imported from Australia being propagated in quarantine at Mapulehu, Molokai.

October



Method of collecting root pressure liquids from the cane plant for chemical analyses.

THE HAWAIIAN PLANTERS' RECORD

Volume XXXV JANUARY, 1931 Number 1

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Molokai Cane Importation Project:

Methods for handling imported cane material either as cane cuttings or true cane seeds are described. Photographs accompanying the article illustrate the equipment and facilities on the island of Molokai now employed in carrying out the quarantine against foreign insects and diseases.

Factory Inspection Observations:

A short survey of recent progress in our manufacturing methods and equipment is presented.

Use of Phosphoric Acid in Improving the Quality of Commercial Sugar:

A. Fries, chemist of Honokaa Sugar Company, contributes a very timely article, which illustrates how certain sugars of poor filtering quality can be greatly improved by the use of phosphoric acid in the mixed juice prior to clarification.

We would appreciate receiving similar articles from our factory men, explaining how they have improved some step in their milling or boiling house practice. Such dissemination of knowledge will greatly aid in furthering the progress of our manufacturing technique.

The Variety Problem in Australia:

The variety problem in Australia was largely a matter of importing established varieties from different parts of the world for trial. At present, importation is only done under quarantine restrictions and seedling propagation and testing are consuming considerable interest. The testing of seedlings for disease resistance is as important as the testing for agricultural value.

The planting of varieties is controlled by a Central Board Committee, and only high sucrose and disease resistant or tolerant varieties are approved for planting. This is reflected in the continued advance in juice quality from year to year. A number of varieties are grown which average higher in juice quality than Badila.

The Forests of Siam:

An article pertaining to the forests of Siam is presented, describing certain species of trees that occur in these forests, methods of cutting and marketing the lumber, etc.

Diseases of the Avocado:

An introductory paper on this subject was presented at the Third Annual Meeting of the Avocado Association of Hawaii, November 25, 1930. Critical studies of avocado diseases in Hawaii, which should serve as a foundation for an authoritative discussion, have not been made. The material is largely an interpretation of the literature as it seems to apply to our local industry.

Java's Sugar Industry:

An article on the sugar industry of Java contains a condensed review of the development of Java as a colony of The Netherlands, the basic reasons for the satisfactory labor supply, the success of the sugar industry and its present-day organization.

Clarification and Its Influences on the Refining Qualities of Sugar:

A brief description of the Dorr clarifier and the Petree process is presented. Clarification experiments, which revealed the causes of the poor clarification at Hamakua Mill Company, are described in detail. Further experiments showing the improvement in clarification that could be secured through the addition of small quantities of superphosphate to the raw primary juice are also presented. The effect on the refining quality of the commercial sugar is discussed when the results of the laboratory experiments were applied to the factory procedure.

Annual Synopsis of Mill Data:

The Annual Synopsis for 1930 is presented. Statistical data and the discussion of technical results are in much the same form as in recent years.

Molokai Cane Importation Project

By J. P. Martin

To carry on a systematic breeding program it is necessary for the geneticists to have at their command a large collection of superior canes as soon as possible. Such a collection may be built up by importing cuttings of desirable varieties or by importing true cane seeds which are collected from tassels of desired crosses made abroad.

A collection of outstanding foreign canes containing both commercial and wild types is being acquired in Hawaii under special rules and regulations as stipulated by the quarantine committee of the Experiment Station in addition to the Federal and Territorial laws and rules governing the importation of living sugar cane material into the Territory of Hawaii. All questions dealing with the importation of cane material are passed on by a quarantine committee composed of the following members: H. P. Agee, chairman; O. H. Swezey, F. X. Williams, C. E. Pemberton, H. L. Lyon, J. P. Martin, C. W. Carpenter, J. A. Verret, A. J. Mangelsdorf and Y. Kutsunai. Within the last year rapid progress has been made on this very important phase of sugar cane culture.

There are serious problems associated with the building up of such a collection of foreign varieties that must receive careful consideration. For instance, methods for handling imported cane material must have been perfected in order to reduce to a minimum the possibility of introducing a foreign insect or disease.

The object of this article is to present the methods exercised in dealing with imported cane material and to show in the accompanying illustrations the equipment and facilities now employed in carrying out the quarantine against foreign insects and diseases. The photographs of these illustrations were taken by various members of the quarantine committee.

As mentioned above, sugar cane material may be imported into the Territory as cane cuttings or as true cane seeds. The following is an outline showing the various measures to which the introduced cane material is subjected before being released to plantations or used for breeding superior canes for Hawaiian conditions:

Imported as Cane Cuttings

1. *Received in Honolulu*, packed in moist charcoal, in sealed metal containers, taken to Molokai and opened in Quarantine House No. 1 for inspection.

Imported As Cane Seed

1. *Received in Honolulu*, in sealed containers either as threshed seed or as fuzz. The threshed seed is planted directly in the germinating house after receiving surface sterilization. The fuzz in its container is opened within a threshing chamber, where the seeds are separated from the fuzz. The seeds while still in the chamber are given surface sterilization, packed in sealed containers, and transferred to the germinating house for planting.

2. *Quarantine House No. 1, Kanoa.* Cuttings are inspected for insects and diseases, thoroughly disinfected externally and are planted in large concrete pots. The varieties are grown for a period of four months, or until the entomologists can certify that no foreign insects are present. Frequent inspections are made by entomologists and pathologists. Selected cuttings are transferred to Quarantine House No. 2 in sealed containers.

3. *Quarantine House No. 2, Kanoa.* The selected cuttings are immersed in water at 52° C. for 15 minutes, which eliminates many organisms if present. Contact plantings are then made with standard varieties in a large soil pit. During the minimum 9 months growth period frequent inspections are made. In the absence of foreign diseases and insects cuttings are taken to Kawela Quarantine Field.

4. *Quarantine Field, Kawela.* During the field quarantine of 12 months the varieties are rapidly propagated in contact with the standard commercial varieties. Repeated inspections of the canes are made.

5. *Release to Plantations.* A critical inspection of the canes is finally made and if they are found to be free from foreign diseases and insects they are cut, boxed and shipped to plantations.

2. *Germinating House, Mapulehu Range.* The seeds are planted in flats of sterilized soil and are handled by the ordinary methods. When growth warrants, the flats are removed to the seedling house for transplanting.

3. *Seedling House, Mapulehu Range.* Individual seedlings are transplanted to sterilized soil in one gallon tins. The seedlings are grown for a minimum period of 6 months with frequent inspections. A rigid examination is made of all plants before cuttings are taken to the planting field.

4. *Quarantine Field, Mapulehu.* Here the seedlings are grown in contact with standard varieties for a definite period. During this time the seedlings are inspected by the entomologists and pathologists.

5. *Release to Plantations.* Since the majority of these seedlings are to be used for breeding purposes, only a few of the superior ones are released to the plantations.

Fig. 1. Site selected for the quarantine houses shown in Fig. 2 at Kanoa. Houses are surrounded by kiawe forests, which make for good isolation. This location is five miles east of the town of Kaunakakai.

Fig. 2. Quarantine units at Kanoa. Caretaker's house at extreme left; shed which houses a steam sterilizer; Quarantine House No. 1 and Quarantine House No. 2. Imported cuttings are first inspected and planted in large concrete pots in House No. 1, and are grown for a period of three to four months. If at the end of this period no foreign insects or diseases are present, cuttings are selected from each variety and removed to Quarantine House No. 2, where they are planted in a large soil pit with standard varieties. The contact planting with the standard varieties makes it possible to determine if normal growth is being secured within the house and also aids in studying abnormalities on the imported varieties should they occur. The canes are retained in Quarantine House No. 2 for a minimum period of nine months, and if they remain free from foreign diseases and insects, cuttings are again selected and planted under field quarantine at Kawela.

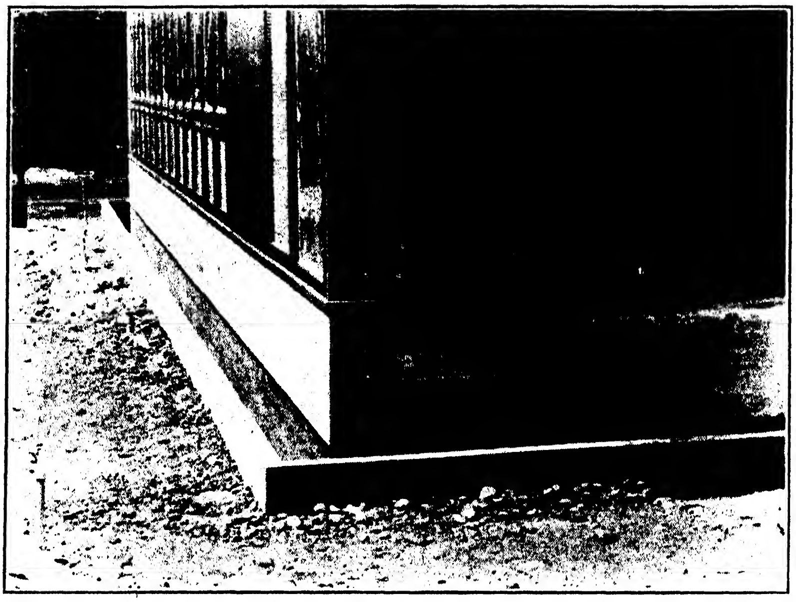


Fig. 3. A moat filled with water surrounds Quarantine House No. 2, which prevents wingless insects getting onto, and possibly into, the house.

Fig. 4. P. O. J. 2878 growing in Kawela Quarantine Field, which is located one mile east of Kanoa. During the field quarantine, which extends over a period of twelve months, the varieties are rapidly propagated in order to have the maximum number of cuttings to forward to the plantations when the varieties are released. Frequent observations are made of the canes while under field quarantine.

Fig. 5. Cutting, inspecting and boxing cane cuttings of P. O. J. 2878 at Kawela Field prior to the release of this variety to plantations.

Fig. 6. A stool of P. O. J. 2878 growing in Kawela Field. This stool exhibits a large number of well-developed stalks. The plantings of this variety were supplied with an abundance of nitrogen in order to promote good growth and rapid multiplication. As a result of this treatment, P. O. J. 2878 produced no tassels in 1929, even though the cane was about one year old.

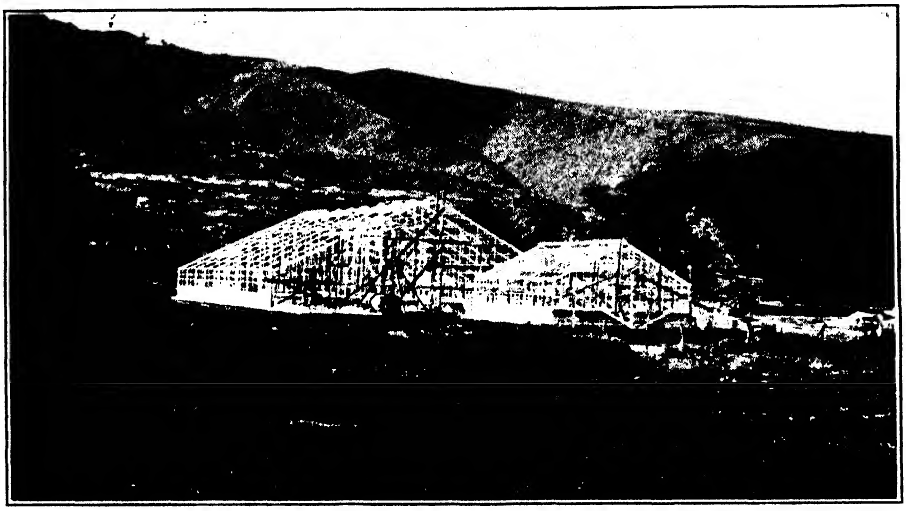


Fig. 7. The Mapulehu Range under construction at Mapulehu, which is situated seventeen miles east of Kaunakakai. This location is well isolated from the Kanoa and Kawela units.

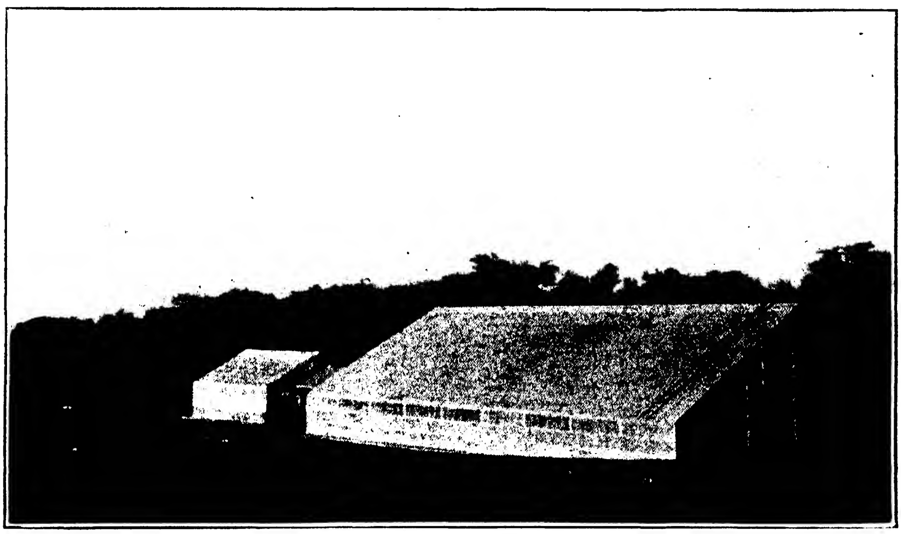


Fig. 8. Mapulehu Range consists of a germinating house connected by a vestibule to a large seedling house. Cane material imported as true seeds is handled at Mapulehu Range, being germinated in the germinating house and later transferred to the large seedling house. Here the seedlings are grown for the remainder of their quarantine, or a minimum period of six months. Frequent inspections are made of the seedlings before they are released. Only cuttings of the seedlings are removed from the house and are planted in a quarantine field at Mapulehu. All cane trash, roots and soil in the pots used for culturing the seedlings are sterilized in a large steam sterilizer and the house is thoroughly cleaned before another lot of seedlings is handled.

Fig. 9. Interior view of the large seedling house of the Mapulehu Range, showing a portion of the Australian seedlings growing in small paper pots. The seedlings are later transferred to one-gallon pineapple tins. The house will accommodate 5,000 seedlings in this manner.

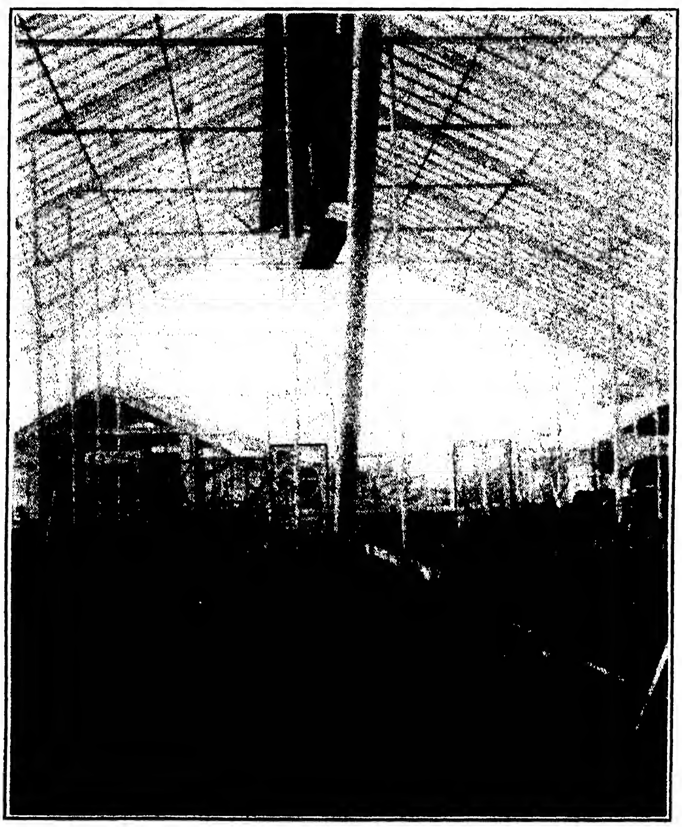


Fig. 10. The Australian seedlings growing in the seedling house at Mapulehu Range. These seedlings were grown from cane seeds which were collected from crosses made by C. G. Lennox in Australia, 1930.

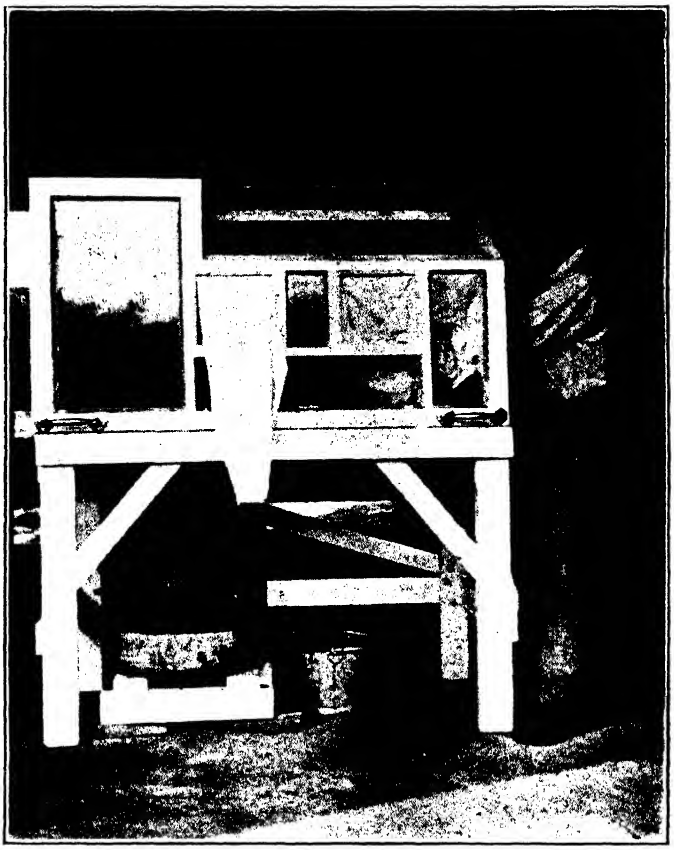


Fig. 11. The threshing chamber where tins containing the imported fuzz are opened and the seeds are separated from the fuzz by methods which prevent the escape of fungus spores. The cane seeds are given surface sterilization while still within the chamber and are packed in small sealed glass vials. The seeds are then planted in the germinating house of Mapulehu Range.

Fig. 12. Planting cuttings of the Indian seedlings at Mapulehu quarantine field after being released from the seedling house. The Indian seedlings were grown from true cane seeds which were collected from crosses made by U. K. Das in India, 1929.

Factory Inspection Observations—1930

By W. L. McCleery

Boiler Feed Water

Condensed vapor from the evaporators has been substituted for raw make-up water at several factories. We consider this desirable because the introduction of scale-forming solids is avoided and heat economy is improved. Using condensed vapor, however, increases the importance of controlling the reaction of the water in the boilers, for without such control the pH will drop to very low points and in the absence of a protective coating of scale, corrosion can be anticipated. The reaction of the water can be corrected without difficulty by adding controlled amounts of alkali in the feed water. Tentatively we have been recommending a pH of 8.3 or moderately higher in the water in the boilers. This point is easy to check as it is the lowest pH at which phenolphthalein indicator will show a red or pink color.

There are now 23 factories making pH determinations on boiler water as a part of the regular laboratory routine. During factory inspections this year the pH was above 8.3 at 21 factories and below at 16 factories. The Boiler Inspection Bureau informs us that corrosion is now much less than before the pH control was started. At least 2 factories, however, this year have had corrosion and at neither factory was any alkaline corrective agent being used to maintain the recommended alkalinity.

Furnaces

Fuel efficiency is now receiving more attention than heretofore. Many furnaces have been redesigned with larger combustion space and tuyeres have been added. The results have been well worth the expenditure. Furnace temperatures have been raised with resulting improvement in fuel economy and higher boiler ratings. In some instances fewer boilers are needed in service than previously, thus allowing ample opportunity for cleaning, inspection and repairs.

Imbibition Water Temperature

Information gathered on factory inspections shows that the majority of the factories are using fairly hot water at the mills. Six factories were applying water before the last mill at a temperature of 200° or over. Twenty-nine factories were using water at 150° or over, eight were below 150°, including one using cold water.

Mill Sanitation

Sanitation has been improved around the milling plants, thereby reducing undetermined losses through fermentation. One factory has done away with the conventional type of juice strainer and cush-cush elevator, and two other factories

have eliminated the elevators and all but short sections of the strainers. These devices have well served their purpose from the mechanical standpoint, but at best they are sources of fermentation loss through sour cush-cush accumulations. The elimination of these devices is now possible through the development of non-clogging juice pumps which have been perfected to the extent that at least three makes of such pumps are now giving satisfactory service.

Copper linings are being used in juice pans and troughs for preventing cush-cush accumulations. Sanitation is thus improved at comparatively small expense as the smooth surface in a large measure keeps the juice flowing freely and cuts down appreciable inversion.

The majority of our milling plants are now washed down regularly with hot water. A hose with a small nozzle using hot water under boiler pressure, and handled with a fair degree of intelligence, will accomplish a very efficient cleaning job with a comparatively small amount of water. The cleaning should be done twice a shift or about every six hours. There are still a few factories that are lax in their efforts toward keeping their milling plants clean.

Entrainment

Sugar loss by entrainment has received our particular attention this year. Factories that were formerly free from entrainment have increased their operating rate to the point that loss on this account is becoming large. Units with baffled calandrias are likely to entrain because of their greatly increased evaporative capacity. The greatest loss is from the last evaporator cell, the sugar being carried away in the condenser leg water.

Many factories test their various condensates with alpha naphthol for traces of sugar. This test, with fresh reagent, is reliable when the condensate is not diluted with condenser cooling water to too large an extent. In condenser leg pipes the condensate is diluted usually with 30 or more parts of cooling water to one part of condensate, and the mixture is too dilute to show any sugar loss with alpha naphthol even though sugar be present in appreciable amounts. For instance, alpha naphthol will give a "light trace" test in sugar solutions of 1 part in 10,000 to 1 in 100,000, but it is not always reliable at the higher figure and is of no value at greater dilutions. In a typical factory grinding 45 tons of cane per hour, producing 50 tons of mixed juice, using quadruple-effect evaporators, 80 per cent evaporation and 30 parts of cooling water to 1 part of vapor in the evaporator condenser, there will be about 650,000 pounds of leg-pipe water going to the sewer each hour. Now if there is only two-thirds of a pound of sugar lost per 100,000 of water, it will not show in the alpha naphthol test, but the loss will be over 4 pounds per hour, or about 100 pounds per 24-hour day.

A loss of 100 pounds per day or 4 pounds per hour in the above illustration is readily detected in making boiling down tests and polarizing the concentrated solution as described in our official methods of analysis. A 50 to 1 concentration with 0.1 reading in a 200 mm. tube will give, under the above conditions, 4 pounds of sugar per hour. One pound per hour loss could be detected by concentrating 100 to 1 and reading in a 400 mm. tube. The boiling down test is needed to determine

the actual pounds loss, if any. It is certain that any leg-pipe water, showing traces of sugar with alpha naphthol, should be concentrated and polarized, as the loss will be sufficiently high to require that preventive measures be taken to improve or install baffles or save-alls in the dome or vapor line.

In making these tests this year Mr. Elliott and the writer have found losses in evaporator condensers amounting to about 200 pounds per hour in 2 factories, and from 9 to 40 pounds per hour in several other factories. A loss of 40 pounds per hour with a 200-day crop amounts to nearly $6,000 even at low sugar prices.

Crystallizer Coils

Factories with water coils in crystallizers, as a means of more rapidly reducing the low grade massecuite temperature now number nine, and more installations are to be in use next season. A number of types of coils are used, but the type originally developed at Ewa is popular. With a cooling water temperature of about 72° F. (22° C.) and about 0.15 sq. ft. of coil surface per cu. ft. crystallizer capacity, the massecuite temperature is brought down to factory temperature in at least 2 days. With warmer water the coil surface should be 0.20 to 0.25 sq. ft. per cu. ft. capacity. By boiling the recommended grain of about 0.2 to 0.3 mm. length, there is usually no danger of false grain, even if the cooling water is started immediately after the crystallizer is filled.

After a massecuite has cooled rapidly there is supersaturation and the molasses has a higher viscosity than when saturated at the same purity. As a means of approximating saturation, three methods are in use. The first is by allowing a sufficient time interval to elapse for the molasses to give up its excess sugar to the crystals. The second is by slight dilution of the massecuite with water dripped into a scroll between the crystallizer and the mixer. A third method is by slight warming of the massecuite by circulating warm water through the crystallizer coils.

One factory has noted a more uniform cooling of the massecuite by increasing the speed of the crystallizer stirrers from the customary one revolution in 2½ minutes to one in a minute and a half. This factory installed coils three years ago, since which time the period in the crystallizer has been reduced from 8 or 9 days to 4 days, and this year the average gravity purity of molasses was 33.9.

Any factory without crystallizer coils that cannot reduce the temperature of the massecuite to approximately that of the boiling house when running at the maximum rate of grinding, should install cooling coils. The full benefit of the coils will not be realized unless centrifugal capacity is adequate to dry the massecuite at high density, but the coils are a means of practically doubling crystallizer capacity at comparatively small cost.

Heaters, Pans and Evaporators

Baffled type juice heaters are now in use at 26 factories. A new development in the Islands is the use of third cell vapor for the partial heating of mixed juice, the final heating to boiling being by usual methods. This method will be used at a second factory next year. New pan and evaporator installations are of the baffled

calandria type and old evaporator calandrias are being modified to the baffled type for greater efficiency.

Settlers and Filters

Dorr clarifiers are now installed in 8 factories and 35 per cent of our total juice is settled by this method. Two factories are, or next year will be, filtering all settlings with Oliver filters. One factory formerly operating the Petree process has for two seasons handled all settlings with Kopke separators, returning the mud to the fields.

Power Plants

A second factory will be equipped with a bleeder type turbine next year. One factory has just finished its first season with a 2500 K. V. A. turbine of this type which operated with perfect satisfaction. All power not required at the factory is used for operating irrigation pumps. These turbines can be operated at any optional exhaust pressure such as 6, 8, or 9 pounds, and all excess exhaust steam not required for maintaining the requisite pressure in the boiling house is condensed at high vacuum in a condenser below the turbine, thus securing a very satisfactory water rate.

International Sugar Congress—New Definition:

Pol, a coined word adopted for international use at the Third Congress of the International Society of Sugar Cane Technologists. Its definition and use, "The value determined by direct or single polarization of the normal weight in a saccharimeter. The term is used in calculations as if it were a real substance."

Improvement in Filtration Rate of Sugar by the Use of Phosphoric Acid

By A. Fries

Phosphoric acid and acid phosphates, in concentrated solutions or in dry or pasty form, have been used in the sugar industry to some extent for many years for the purpose of neutralizing excess of lime, or to hasten the precipitate of slow settling juices. As an aid to clarification its use in Hawaii has been limited. Clariphos, a concentrated solution of phosphoric acid, materially improved the appearance of the clarified juice of certain fields at Pióneer Mill fifteen years ago. S. S. Peck in the same year "obtained great assistance from a clarifier made by the Pacific Guano & Fertilzer Company," in his clarification of the separated mill juice at Kahuku. W. R. McAllep, in a report on clarification in 1923, wrote:

> The amount of phosphoric acid present is a very important factor, affecting the clearness of the clarified juice. With the ordinary clarification method, using lime and heat only, we have never obtained clear clarified juice with a deficient amount of phosphoric acid. On the contrary, we have never failed to secure clear juice by liming to the approximate point in the presence of a sufficient amount of phosphoric acid. Adding phosphoric acid to the juice has the same effect as if it were originally present.

Its use has been recommended by the Experiment Station and its advantage demonstrated during factory inspections.

In the following we wish to show that by the systematic application of soluble phosphates to the mixed juice, both filtration rate and color of the sugars can be improved at Honokaa.

The low filtrability and the poor washing quality of our sugars made it imperative that something be done in the sugar house, to effect an improvement. While changes in the clarification equipment, greater centrifugal capacity and speed, or the double purging would undoubtedly contribute to the production of a better sugar, we felt that if we could reduce by chemical means such material in our juices, which retard filtration, a higher filtration efficiency in the end product would be achieved. The use of phosphoric acid suggested itself. That the heavy precipitate of calcium phosphate improves an otherwise turbid juice, can easily be seen by the appearance in the test tube and is shown in a few laboratory experiments.

TREATMENT

Cane Var.	Mixed Juice Purity	No Phosphate pH, Hot	No Phosphate Clarity	Phosphate Lbs. per Ton Cane	Phosphate ph, Hot	Phosphate Clarity	Increase in Clarity %
Mixed	75.0	7.9	2.1	.66	7.8	2.7	29.0
Uba	75.6	8.0	1.1	.86	8.0	1.9	73.0
Mixed	75.3	7.8	2.5	.86	7.8	3.3	32.0
Mixed	78.0	8.0	2.4	.80	8.0	3.9	63.0
D 1135	78.9	8.1	2.3	.40	8.1	2.8	22.0
D 1135	82.6	8.1	2.3	.66	8.1	3.0	30.0
Uba	72.4	8.1	1.5	.86	8.1	2.4	60.0
D 1135	81.7	8.1	1.9	.54	8.1	2.2	16.0
D 1135	82.6	7.9	2.2	.60	7.9	2.7	23.0
D 1135	80.5	7.8	2.0	.54	7.9	2.7	35.0
Average	78.3	8.0	2.03	.68	8.0	2.76	36.0

Beginning July 15, 1930, Honokaa Sugar Company added phosphoric acid in the form of double superphosphate to *all juices* which were deficient in phosphoric acid and in such proportions as to bring the total P_2O_5 content up to .03 or .035 per cent. The benefits we have obtained in the factory so far are: Cleaner juices, higher syrup purity and better sugar.

The Refinery reports on two sugar shipments as follows:

First shipment, 1806 tons:

It is interesting to note that the Honokaa shipment on the *Mala* showed a marked improvement in filtrability. In comparison, the filtration efficiency of 68 per cent is 23 per cent higher than the figures of 45 per cent for the previous 1930 shipments from Honokaa. The washing quality shows a similar change.

Second shipment, 1557 tons:

The Honokaa shipment on the *Mana* ranked the highest in filtration efficiency for any 1930 shipments from this factory. This improved filtrability of the Honokaa raws has been particularly marked during the last three months, when the efficiencies have increased from 40.8 per cent for August to 68 per cent for October and to 72.5 per cent for this *Mana* shipment in November.

From the foregoing it is evident that the better clarification with the probable absorption of colloidal substances in the flocculent phosphate precipitate had its effect on the "refining quality" of the sugar. It is also evident from the laboratory figures during that period.

	No Phosphate	Phosphate	Difference
Cane per Hour	44.79	47.08	2.29
Clarity Readings	2.2	2.8	.6
Purity Increase from Mixed to Syrup	1.59	1.82	.23
Average Weekly Filtration Rate	40.0	71.0	31.0
Purity Final Molasses	37.99	36.75	1.24

Our good low grade work is, we believe, in some measure due to the improvement in clarification. The low syrup purity (77 to 80) put a heavy load on the capacity of the low-grade station. The high percentage of non-sugars considerably increased the low grade product of 65 to 70 purity and to make this into a

marketable sugar, *all* strikes for weeks had to be boiled on syrup and remelt only, giving a crystallizer molasses of 54 purity. That these sugars showed marked improvement in both filtrability and washing quality is most noteworthy.

Four crystallizers were filled in 24 hours (23 per week), actual boiling time per crystallizer about 4½ hours, time for cooling, without cooling coils, from 4 to 4½ days, and yet, considering the difficulties we usually have in this station, we managed to purge all this low grade massecuite without any change in centrifugal capacity or speed, producing a final molasses of considerable lower purity. These results are so far interesting, as they confirm our opinion that it is unnecessary (and probably harmful) to boil a low grade strike for 20 or more hours; also that the cooling of the crystallizers to a very low temperature makes much greater demands on the centrifugal capacity, without adequate compensation for a lower molasses purity.

The cost for material so far amounts to about 15 cents per ton of sugar, or the equivalent of about 4½ pounds of sugar at present prices. We feel convinced that these 4½ pounds of sugar find their way into the bags in higher recovery from a better syrup and a better exhaustion of molasses. The above laboratory figures would indicate a .7 per cent higher recovery, equal to about 16 pounds of sugar per ton manufactured. We do not claim that such a plus recovery should be credited to a better clarification alone, however an increase in syrup purity of only .05, and a lower molasses purity of only .4 should pay for the extra cost of manufacture. As the P_2O_5 which has been added is recovered in the press cake and presents an available plant food, this fertilizer value of the calcium phosphate should be deducted from the cost of the material used.

Summing up, the practice of adding phosphoric acid to the juices might be recommended both from the standpoint of the raw sugar manufacturer and the refiner on all those plantations where there is difficulty in meeting the demands for a better refining quality of the sugars.

The Variety Problem in Australia

By C. G. Lennox

The problem of maintaining and improving yields through better sugar cane varieties has been more carefully worked upon by the Australian farmers than any other phase of sugar cane agriculture except, possibly, efficiency in cultivation. Both problems appeal more strongly to the creative imagination and are more easily visualized than complex soil amendment formulae or growth curve cycles. The result is that one finds nearly all the farmers keenly interested in both problems. The use of varieties has shown the farmer a cheap way to increase yields without any additional field expense. Their trial in the field offers something tangible, something the worth of which the farmer can watch and judge for himself. With this thirst for more varieties to plant in competition with their standard canes, it is little wonder that organizations and individuals turned to the simplest means, that of bringing in cuttings of recognized varieties from other parts of the world. This procedure was followed for more than fifty years without restrictions of any sort, and cuttings of more than 680 varieties have been introduced and planted in some one of the sugar regions. In addition to these introductions there has been an extensive exchange of sugar cane cuttings between different sugar growing regions. As a result of this unrestricted movement of cane cuttings, we find many of the world's severest systemic diseases securely established in the Australian sugar belt. The present-day variety problem is, therefore, very closely linked with the disease problem.

Importations

Prior to 1874 and until 1925, some 680 varieties were imported without restriction. The majority of these were brought in from New Guinea or neighboring South Sea islands. Other countries which have contributed are Mauritius, Java, Demerara, India, Hawaii, Louisiana and other sugar-producing countries. It is significant that of this great number introduced only a very few can be found at present, but these few produce approximately 75 per cent of the Australian cane tonnage. Badila (N. G. 15) alone produced approximately 45 per cent of the 1929 crop.

Importations at the present time are permitted only under strict quarantine measures. The Queensland Bureau of Sugar Experiment Stations at Brisbane and the Colonial Sugar Refining Company in Sydney are the only agencies handling the importation of cuttings from foreign countries. At Brisbane cuttings are planted in isolation gardens some distance from sugar cane regions and are not distributed until they have been carefully observed by the pathologist over some period of time. At Sydney, the Colonial Sugar Refining Company maintains gardens as well as an insect-proof greenhouse similar to the type used in Hawaii. New varieties are grown one year in this house before being released for planting in isolation areas in the regions at their mills in Fiji as well as Australia.

Breeding of Sugar Canes

As early as 1889, an organization known as the Queensland Acclimatization Society prepared to collect tassels for seedling propagation. Between 1890 and 1907, this Society raised some 1800 seedlings. The letter "Q" was attached to these varieties, of which there is one still in prominence known as Q 813.

W. Clark, working for the Colonial Sugar Refining Company at their Hambledon Mill, started to propagate seedlings about 1901 and continued through 1905 when he moved the breeding work to Colonial Sugar Refining Company mills in Fiji. This location was climatically ideal for seedling raising and with a good assortment of varieties from different parts of the world in his nursery he was able to make many crosses. The letters "H. Q." (Hambledon Queensland) are prefixed to the seedling raised at that station. The variety H.Q. 426 produced about 11 per cent of the Queensland sugar crop in 1929. The varieties H.Q. 409 on the Herbert River and H.Q. 5 in New South Wales have both become prominent in recent years because of their resistance to the gumming disease.

The work of seedling raising in Australia practically ceased between 1905 and 1921. At this time the Queensland Government Bureau of Sugar Experiment Stations started to propagate seedlings at their South Johnstone Station. The varieties produced here have the letters "S.J.Q." prefixed. At the time of the writer's visit in 1930, three varieties, S.J.Q. 4, 7, and 28, were showing considerable promise. Only S.J.Q. 4 and 28 were released officially to the farmers for propagation because all cultures of S.J.Q. 7 were infected with leaf scald.

Sugar cane breeding is at present being carried on by two separate agencies. The work for the Bureau of Sugar Experiment Stations is continuing at South Johnstone under the direction of Mr. Barke, the chemist in charge of the station. The technique used in crossing, as well as planting and germination, is very similar to that used in Hawaii. Germinated seedlings, as well as seed-bearing fuzz, are distributed to the government stations at Mackay and Bundaberg where the seedlings are planted in the fields and selected for the regions which these stations represent. A good collection of breeding material was planted in the Freshwater district near Cairns during the past season where weather conditions are more suitable for crossing work than they are at South Johnstone 60 miles south.

The Colonial Sugar Refining Company is carrying on a separate breeding project at its Macknade mill on the Herbert River. The work here is under the direction of K. Gard and the technique he follows is similar to that used in Hawaii. A portion of each year's crosses is planted in this region for selection and testing; the remainder is sent to Fiji and the Grafton Experimental Farm.

A third agency involved in the propagation of seedlings is the New South Wales Department of Agriculture. Seed-bearing fuzz is imported from different parts of the world and planted at the state government's experimental farm at Grafton, a point about fifty miles south of the most southern sugar cane region. Selection work is carried on here in cooperation with the Colonial Sugar Refining Company officials at Broadwater.

Selection and Testing of Seedlings

The early stages of selection work are all carried on at the experiment stations or in the mill nurseries. Following the first selection from the seedling stool, all further selections are based largely on juice quality. Varieties of low juice quality are quickly rejected. All seedlings raised by the above-mentioned agencies which reach the final stage in field tests are planted in a gumming-disease test before being released to the farmers. The seedlings showing susceptibility are not released.

Variety Tests

Practically no use has been made of replicated variety tests in the field to determine the superiority of one variety over another. Changes in variety have been due largely to disease in old varieties, reputation of new varieties or appearance of a couple of lines of a new variety growing alongside the old variety. The difficulties of carrying on reliable variety tests on a small farm are many, but within the past few years the Bureau of Sugar Experiment Stations has successfully installed a few tests in the "Latin Square" plan.

Commercial Planting of Varieties

The farmer is not free to plant any variety he may choose. He can send to the mill only those varieties which are listed as approved for his region by the Central Board (a board representing the government, millers and farmers). This control of plantings has arisen to protect the factories from receiving expensive milling canes of low quality and to protect the industry as a whole from severe disease epidemics by not allowing the planting of very susceptible varieties. Should a farmer send a disapproved variety to the mill it may or may not be accepted, depending on the management's decision. This policy of controlled variety planting has created two distinctive features in the variety situation today which would not likely be found if it was not in force. In the first place we find the whole Australian sugar crop coming from a comparatively few varieties, a condition not likely to exist in an agricultural crop coming from small non-organized yeoman units. Secondly, we find a yearly bettering of the juice quality for the whole crop, but no betterment of tons cane per acre.

The following table represents the per cent of the total crop produced by the different major varieties grown in Queensland. These figures were furnished by the Chairman of the Central Board and do not include figures from New South Wales or Colonial Sugar Refining Company mills:

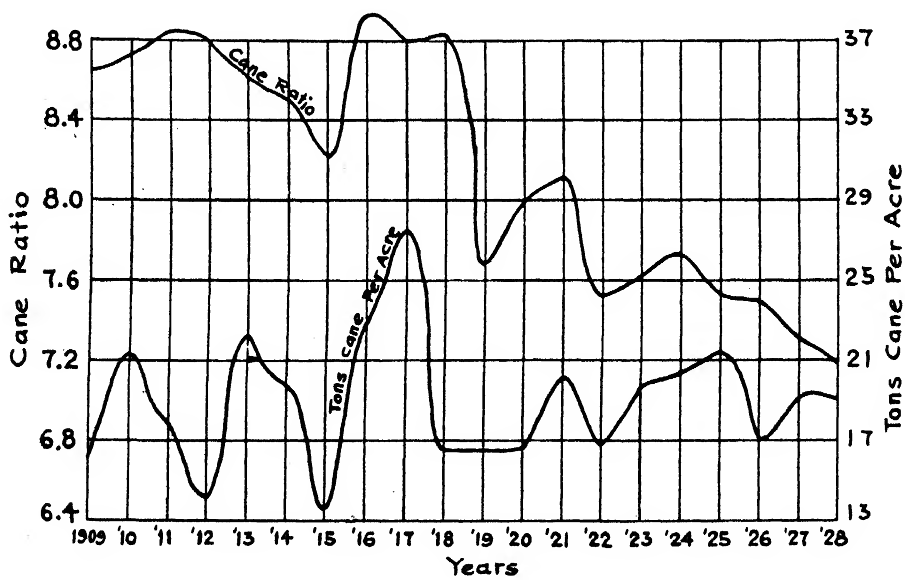
District	Badila	D 1135	H.Q. 426	Q 813	M 1900	E.K. 28	Other Varieties
Cairns & Innisfail......	84%	4%	6%	..%	..%	..%	6%
Lower Burdekin	39	..	22	1	2	19	17
Proserpine & Mackay...	15	3	17	22	20	6	17
Bundaberg & Isis.......	3	33	..	13	14	..	37
Maryborough & Nambour	2	28	..	32	7	..	32
All of Queensland......	45%	8%	11%	8%	7%	5%	16%

The following table details the varieties in order of importance which are grouped in the above table as "Other Varieties":

District	Varieties
Cairns & Innisfail	Pompey, N.G. 24
Herbert River	H.Q. 409, Badila, Oramboo, Nanemo, Korpi, Q 813, M 131, N.G. 24, M 1900
Lower Burdekin	B. 208, Oramboo, N.G. 24, Pompey
Mackay	Malagache, P.O.J. 2714, Pompey, H.Q. 285, B 208, Uba
Bundaberg	Uba, P.O.J. 2714, H 227, Many others.

The following graph shows clearly the second influence of controlled variety planting, that of improving the juice quality of the crop as a whole. It is to be noted that although the cane ratio improves, the tonnage of cane per acre shows no gain. The premium offered by the mills for high sucrose cane is so attractive that the farmer is constantly striving to crop only varieties of the highest sucrose content even if their per acre yield of cane is a little lower.

Yearly Average Cane Ratio and Tons Cane (short tons) Per Acre For The Australian Cane Sugar Crop



The high juice quality of the Australian sugar cane crop has always been a matter of considerable interest. The reasons for this have been partly covered in the above discussion, but these factors, namely, enforced planting of high sucrose varieties and a higher scale of payment for cane of high sucrose content, have only aided in improving an already good sucrose average. The greatest factor may be considered the weather conditions which accompany the harvesting season which is characterized by little rain and low temperature. Other influencing factors may be a reduction in fertility of the land (for little is returned in proportion to the amount removed) and increased milling efficiency.

The following table gives the performance of a few of the main varieties during the 1929 milling season. The mills are representative of the sugar areas from Mackay to Cairns:

	Mulgrave Central		Babinda Central		Mourilyan Mill		Pioneer Mill		Racecourse Coop.	
Variety	% of Crop	Av. Q.R. for Crop	% of Crop	Av. Q. R. for Crop	% of Crop	Av. Q.R. for Crop	% of Crop	Av.Q.R. for Crop	% of Crop	Av. Q.R. for Crop
Badila	68.6	6.64	88.04	6.58	94.9	6.38	27.5	6.45	...	...
D 1135	14.1	6.63	.40	7.22	...	...	...	...	1.3	6.97
B 147	5.3	6.64	.09	6.27	...	...	...	...	...	...
H. Q. 426	10.7	6.08	7.96	6.44	2.7	6.58	26.1	6.55	25.	6.31
Goru (N.G. 24)	...	...	1.21	6.57	...	...	3.9	6.73	...	...
Q 813	...	...	.48	6.39	.16	6.52	...	...	31.9	6.37
M 1900	...	...	...	...	...	...	...	...	17.2	6.65
E. K. 28	...	...	.01	8.54	...	...	22.5	6.66	7.2	6.41
Pompey (7R 428)	...	...	...	...	2.05	7.31	...	...	1.3	7.2
B 208	...	...	...	...	.03	6.25	11.	6.12	...	...
Uba	...	...	...	...	...	...	...	...	.21	7.14

Note:—The Q.R. figures used are the reciprocals of the Commercial Cane Sugar figure used in Australia.

Australian Varieties of Interest to Hawaii

A task which would border on the impossible would be for one to pick varieties of sugar cane which may be superior in Australia and expect them to be also superior in Hawaii. The growth conditions for the two places are totally different. A superior cane in Australia is one which can make the most of a short intensive six months season of growth and be ready to harvest about twelve months after it was started. To ask a cane to carry through two growing seasons in Queensland would be fatal; in Hawaii it is expected. Besides this single big difference there are many others, as: upright cane vs. recumbent, long periods of dormancy of ratoons vs. immediate starting of ratoons, non-burning before harvest vs. burning before harvest, resistance to disease vs. no presence of same diseases in Hawaii, and many such minor points of difference that a variety chosen as superior in the one place would likely not continue to be superior in the other. With these considerations in mind it is quite impossible to think that any of the better varieties there will do wonders here. The writer believes the following would have some interest if imported to Hawaii:

B 208, considered the "sweetest cane in Australia," big stick, closes in well, germinates and ratoons well, rarely tassels. Possibly of commercial value but very interesting for breeding purposes.

H.Q. 426, generally sweeter than Badila, big stick, considered good on medium to poor soils, germinates well, but closes in rather slowly. Rarely tassels. Early maturer. N.G. 24 (Goru) is female parent. Possibly of commercial value. Blood line well represented in seed brought from Australia in 1930.

Summary

The insect and disease problems in the Australian sugar industry are living examples of the results of importing sugar cane cuttings from all countries of

the world without restriction. Importations are now permitted only under rigid quarantine.

The breeding of sugar cane seedlings was spasmodic for twenty years. Within the last few years an organized effort has been made to start a breeding and selection program.

A system of controlled planting of only approved varieties of high sucrose content as well as a higher rate of payment for cane of high sucrose content has tended to increase the juice quality of the whole crop.

The 1929 season's Quality Ratio figures from five representative mills show H.Q. 426, B 208 and Q 813 to average better in juice quality than Badila.

The Forests of Siam

By L. W. Bryan

The following article is taken in part from data supplied by the Siam Royal Forestry Department and from notes taken by the author during his recent trip to that country.

Roughly speaking, Siam covers an area of about 200,000 square miles, and of this area about 60 per cent is covered with tree growth of some kind. The climate is tropical, the northern latitude being 21 degrees (about the same as Kauai), and extends south to 5 degrees north.

Teak Forests

The teak forests are the most valuable and important of all the state forests and cover an area, in the northern part of the kingdom, of about 11,000 square miles. This teak section is hilly and mountainous in places, although the highest mountain in Siam is only 8,500 feet above sea level (Mt. Angka). Teak in Siam, however, does not grow up to any elevation, about 2,500 feet above sea level being the limit of its range.

The average rainfall in the teak section is about 50 inches per annum, and the species *Tectonia grandis* seems to grow best in soils derived from granite, sandstone and limestone and must have good drainage. While young it is rapid in growth, but soon slows up so that during middle life and old age it is very slow and takes about 150 years to produce a trunk three feet in diameter. The largest teak tree known in Siam is 10 feet in diameter (breast height), and 150 feet tall. Teak does not form large areas of pure stands, but is often found mixed with other trees, a number of which are trees that produce merchantable timber of considerable value, such as *Pterocarpus indicus, P. macrocarpus, Lagerstroemia calyculata* and *L. balansae*. The wood of these species will float under certain conditions and can, therefore, be cheaply transported along with the teak by water, while the heavier woods, that will not float, must be left behind in the forest.

All of the State teak forests are under the control and administration of the Royal Forestry Department. This department is a well-organized branch of the government, coming under the control of the Minister of Agriculture, with well-trained foresters who have entire charge of all leases and cutting operations on the government-owned properties. In the teak zone there are six forest divisions, each in charge of a division head.

At present there are twenty-eight leases in force to cut teak. These leases run for fifteen years and are subject to the following conditions:

1. All trees to be cut must be selected and girdled by employees of the forestry department.

2. No tree with a girth of less than 7 feet can be cut, and 6 per cent of the best trees are reserved for seed trees.

3. Metric measure is used and charges are based on measurements made by the forestry department.

4. All trees must be cut close to the ground in order to eliminate waste.

5. Certain valuable trees, other than teak, have been placed in a reserve class and are protected by a royal decree and can only be cut under special permit.

Trees in the unreserved class (usually species of an inferior type) can be cut without restriction, and free permits are issued to local people to cut certain reserved trees for home use, religious or charitable purposes.

About 85 per cent of the teak forests are worked by foreign firms. The Brandes Selection System of management is in use and the falling cycle has been set at thirty years (which is the number of years required for the smallest tree in the girth class below that of the exploitable girth [7 feet], to grow and become of exploitable size). The trees to be felled are first selected, measured, numbered and then recorded by the forest officer in charge of this work. Then it is girdled by cutting a ring about 4 inches wide around it through the bark and cambium. This kills the tree slowly and each tree is girdled about two years before felling time. This is done in order to permit it to dry out and become seasoned. Practically all of the teak timber is brought from the forests to the seacoast and mills by floating it down the rivers. Green teak logs are too heavy to float, so it is first necessary to season and dry the trees before felling.

The actual felling is done with saws and axes in much the same manner as here and elsewhere. All trees are cut as close to the ground as possible and are then cut up into logs of suitable lengths and marked with their owner's brand or identification mark. All felling is done during the rainy season when the ground is soft and less likely to damage a falling dry tree.

Trained elephants are used to skid the logs from the place of felling to the river bank. This operation also takes place during the rainy season when the ground is wet and slippery and the logs slide more easily. The elephants used are well trained and are reputed to be the most intelligent draft animals in the world, and from what the writer saw of them this is believed to be true. They are expensive to maintain, however, and are easily injured, so in some sections they are being done away with and replaced by more modern methods.

The logs, after entering the water, are driven down stream in much the same manner as on our own mainland. After they have been driven down the smaller streams, past all rapids and "white water" into the larger rivers, they are sorted out according to their brands, and each firm's logs are rafted together and floated down to the seacoast or other destination. These rafts contain about 200 logs each and it requires about five years from the time a tree is felled before it reaches its final destination at the seacoast. Some logs are transported in other ways, but the large cut is handled by water.

Upon arrival at the Forest Duty Station the logs in the rafts are measured and dues are collected. The logs are then graded; some are sold, while others are taken on to different sawmills, where they are cut up into dimension material, the best of which (about 55 per cent) is exported. The annual amount thus exported is about 2,500,000 cubic feet.

Teak is considered one of the most valuable timber trees in the world. It is used for all sorts of purposes and is considered the finest of shipbuilding material. It contains little sap wood and the heart wood contains an oil which is its chief preservative. When new it is dark golden yellow, but with age becomes almost black. It is very durable and has been known to last from 500 to 600 years when used in buildings. It is one of the few tropical trees that produce annual rings.

In addition to the teak forests there are several other types, such as evergreen forests, deciduous forests, coniferous forests, mangrove swamp forests, and others.

Evergreen Forests

The evergreen forests are scattered over Siam and consist of two types, the tropical evergreen and the hill evergreen. The former grows up to about 3,000 feet elevation, where it is replaced by the hill type. This hill type, as a rule, is thick and impenetrable and is little known or explored as yet and has practically no commercial or economical value at present.

The tropical type, however, is fairly well known and produces much of value. It is made up of many different species, several stories high, which form a thick, often impenetrable, jungle. The family Dipterocarpaceae, is well represented by many species which are found throughout this type and produces a large percentage of the best timber. Several other species occur that also produce valuable wood, such as Dalbergia spp., *Mesua ferrea, Diospyros mollis, Afzelia bakeri, Cotylelobium lanceolatum,* Lagerstroemia spp., *Mansonia gagei, Aquillaria agallocha,* etc.

The logging operations in this type of forest are much the same as in the teak forests and are under the control of the forestry department. In addition to sawmill material, other products are obtained from this type.

The Royal Siamese Railroad burns wood in its locomotives on the southern division and consumes some 120,000 cubic meters each year, a large part of which comes from this type.

Bamboos and canes are also utilized, and quite an export trade has been built up.

Gutta-percha, as well as other gums, oils and resins, is also obtained from this type of forest in commercial quantities, all of which are gathered and a large percentage exported.

Coniferous Forests

The coniferous forests are located in northern and central Siam above 2000 feet elevation and are composed chiefly of two species, *Pinus khasya* and *P. merkusii.* At present they are too isolated to have any commercial value although a small amount of resin is gathered and used locally.

Mangrove Swamp Forests

There are some 300,000 acres of these swamp forests in Siam located along the seacoasts and made up of a limited number of species suitable to this type, the most important family being Rhizophoraceae, to which the true mangrove (Rhizophora spp.) belongs. That most useful palm, *Nipa fruiticans,* is also found grow-

ing in this type of forest. Good timber is secured from *Ceriops candolleana, Carapa moluccensis* and *C. obovata,* while small to medium-sized saw logs are secured from two species of the true mangrove, *Rhizophora conjugata* and *R. mucronata.*

Fuel and charcoal are also produced in large quantities and it is here that the trade in these products has reached its greatest development in Siam.

Mangrove barks are also gathered and exported in large quantities. They are used for tanning and dyeing purposes.

Deciduous Forests

These forests, which are known locally as "Pah Peh," occur in different parts of the kingdom and contain many species of valuable timber-producing trees. They are open in type with grassy undergrowth, subject to repeated ground fires, and are deciduous during the dry season, when they drop their foliage. Here, again, the family Dipterocarpaceae produces a large part of the worth-while timber. Cutting is done under government control in most sections, based on the royal decree of 1914. Under this authority all trees are divided into two sections, (1) unreserved trees, and (2) reserved trees.

Anyone can fell and use trees in the first section. Those in the second section are divided into three divisions, (a) very valuable trees which may not be cut at all, (b) valuable species of trees, and (c) less valuable species of trees. Minimum girths for reserved species are set by law and those wishing to cut trees in divisions (b) and (c) may do so by first securing a permit and paying certain fixed royalties. This also applies to any by-products obtained from trees in these divisions, such as gums, oils, resins, etc. Permits are not issued to cut trees in division "a" as these trees are considered too rare and valuable and are being retained for propagation purposes.

Diseases of the Avocado

By C. W. Carpenter

The diseases of the avocado have received comparatively little attention from pathologists in Hawaii. This introductory paper on the subject was presented in abbreviated form at the Third Annual Meeting of the Avocado Association of Hawaii, November 25, 1930, at the invitation of Dr. W. D. Baldwin. The material is largely an interpretation of the literature as it seems to apply to our local industry. Critical studies of the local avocado diseases, which should serve as a foundation for an authoritative discussion of the subject, have not been made. If this paper serves in any degree to clarify the confusion that exists in the subject of avocado diseases, its purpose will have been fulfilled.

In Hawaii, the various spots and blemishes of the avocado fruit have not been clearly differentiated or the causes ascertained with sufficient accuracy to be of much value. The literature from other countries is often not accessible and offers too much confusion of names of diseases and causal parasitic organisms to be readily useful to the avocado grower. A similar condition prevails with the diseases of the leaves, branches and trunk of the tree.

This discussion of local avocado diseases is chiefly concerned with those caused by parasitic fungi, yet mention will be made of certain blemishes of other origin which are likely to be met by the growers. A few remarks about the nature of

Spores of avocado black spot fungus. X 320.

fungi are necessary to a simple and brief discussion of fungous diseases. The fungi concerned are minute plants with the general characteristics of the molds often seen on bread or vegetables stored in damp places. There are an almost infinite number and variety of these fungi, differing in habit of growth and manner of fruiting. The great majority obtain their food from dead organic matter, a considerable number live at the expense of living or dead plant material as occasion requires, while relatively few are strictly parasitic. The fungi are propagated and spread chiefly by microscopic spores (see illustration), which are comparable to the seeds of higher plants. These spores, formed in countless numbers under favorable conditions, are responsible for the rapid spreading of fungous diseases, since they are readily carried by wind, spattering rain, garden tools, etc.

If one considers the descriptions of avocado diseases from various localities, the local names applied are very confusing. Of the semitechnical names, the term anthracnose has been much abused. This name indicates a disease or blemish of pustular or ulcerous type and has been so loosely used as to have little significance. It is commonly used, however, for the numerous diseases caused by the fungi known as Colletotrichum and Gloeosporium, two practically identical groups of fungi. In the literature the following diseases of the avocado are discussed separately with distinctive names for each trouble according to the part of the tree affected, or the parasitic fungus suspected: anthracnose of leaf, leaf blight, rusty leaf blight; anthracnose, die-back and wither tip of branches and fruit spurs; blossom blight, black fruit spot, bark rot and canker or girdling of branches and trunk. Yet all appear to be caused by very closely related species of Colletotrichum or Gloeosporium, the anthracnose fungi. Reasons will be presented below for considering this formidable array of diseases as the manifestations of one fungous disease on various parts of the avocado tree. Until the contrary shall be demonstrated, it simplifies the subject considerably to adopt this viewpoint.

A similar confusion long existed with respect to the various manifestations of the similarly named diseases of the apple—the black fruit spot, leaf spot and canker. It is now recognized that in its various stages this apple disease affects (1) the fruit, causing blemishes and rot; (2) the limbs and twigs, causing blight and die-back; and (3) the leaves, causing the spots known as "frog eye". The fruit rot first claimed attention and was described by various names, as for example: black rot, ring rot, blossom-end rot and brown rot. On the bark the disease was described as die-back, twig blight, apple canker, black rot canker, black rot, and New York apple tree canker. On the foliage the disease was termed leaf spot, leaf blight, brown spot and frog eye. Various fungi found on leaf, twig and fruit were held responsible for the respective diseases. Finally one fungus was determined to be the cause of the several forms of disease and it was considered to be the species named *Physalospora cydoniae* Arnaud. The genus Physalospora represents the higher fruiting stages of the genera Gloeosporium and Colletotrichum.

The analogy of the history of black spot and canker of apple and of avocado is close. It does not appear presumptious to predict that in this same way the Hawaiian avocado diseases, black spot, leaf spot, die-back or wither tip and bark canker, will be ultimately demonstrated to be due to the single fungus, *Physalospora persea* Doidge. This fungus, already determined elsewhere as the higher stage of

the avocado Gloeosporium or Colletotrichum, is closely related to the apple Physalospora, above mentioned.

Brief extracts of the descriptions, by various authors, of bark canker, leaf spot and black rot, as well as of several other fruit spots, are presented below. The probability that the symptoms of the diseases may be somewhat different on the several varieties of avocado should be appreciated.

Bark Canker, Leaf Spot and Black Spot of Fruit

Doidge (1) describes the bark cankers of avocado as they occur in the Louis Trichardt district of the Transvaal, South Africa, as follows:

> In the earlier stages of infection the bark becomes sunken and discolored, the diseased area gradually increasing and girdling the branch. Small branches, not exceeding two to three inches in diameter, are killed, while extensive cankers are formed on the larger limbs and trunks. The boundary between the healthy and diseased tissue is marked by a raised, reddish-brown line . . .
>
> The mycelium penetrates the cortical tissues and reaches the wood, where it is apparently confined to the medullary rays.
>
> The disease can probably be arrested in its early stages by excising all diseased twigs and stem cankers, and painting the wounds with a disinfectant wound dressing.

The following description of black spot of avocado fruit is quoted from Stevens (2).

> The injury appears as definite spots scattered over the surface of the affected fruit. These spots are round, brown to dark brown or black in color, and vary from one-eighth to one-half of an inch in diameter. They are composed of hard, dry, corky tissue which penetrates the skin of the fruit down to the meat.
>
> The surface of a spot is slightly sunken, often cracked or fissured, and in some cases a zonated effect is observed. When once formed, the spots do not appear to increase in size on the surface of the skin, but a decay of the meat below may follow, especially in matured fruit. Affected fruit may show a few or many spots of various sizes. Frequently, spots merge to form irregular patches, the surfaces of which are deeply cracked or broken. Severe attacks on less matured fruit may misshape or dwarf them.
>
> Spots also appear in the bark of young shoots and on fruit stems somewhat similar to the spots on fruit. Infections on the fruit stems generally appear some time in advance of those on the fruit.

A description, probably of the same fruit spot, is given by Abbott (3) under the title "Anthracnose of the Avocado in Peru." This paper presents a comprehensive description of the "anthracnose" as one disease affecting various aboveground parts of the avocado tree. The anthracnose is attributed to *Physalospora persea.* Three paragraphs are quoted:

> Anthracnose may attack any of the above-ground parts of the tree, but its most serious damage is caused when the main trunk and fruiting branches are involved. On these organs the infection begins as a dark reddish-brown area, which enlarges gradually, usually more rapidly horizontally than vertically, until it forms a lesion which eventually girdles the affected part. The canker is at first sunken, especially in young, tender tissue, but as the disease advances the bark dries, cracks and buckles out, giving the affected portion a bulged appearance. The dried bark sloughs off and the limb dies slowly. The sap of the tree flows out

through the cracks in the bark and on drying leaves a whitish, crystalline substance, the presence of which is characteristic of the disease. The fungus has not been observed penetrating into the woody portions of the trunks or limbs, the infection apparently being limited to the cortex.

On the fruit anthracnose produces round, sunken, reddish-brown spots which are usually from one to two centimeters in diameter. The centers of the fruit lesions may be pale pink in color caused by the production of spores of the fungus. As a rule the decay does not extend deeply into the flesh of the fruit, although the diseased spots offer ideal means of entrance for other fungi, particularly *Rhizopus nigricans*, which may cause more rapid decay of the fruit than the anthracnose itself. The decayed areas have only rarely been observed penetrating to the seed.

On the leaves the disease causes circular, chocolate-colored spots. Infected blossoms may turn black and fall. Leaf and blossom infection, however, is of secondary importance compared with the damage which is caused to the tree by the destruction of the trunk and branches and the rotting of the fruit.

The avocado fungus probably gains entrance to and infects the flowers, the young twigs, fruit spurs and the leaves under favorable weather conditions and also enters small wounds or sunburned places on the branches and trunk. This fungus is said to be a weak parasite which possibly requires some predisposing factors to favor its entry, such as lowered vitality from overbearing, malnutrition or poor drainage. Favoring conditions are wet weather at flowering time, sunburn injury, wounds of fruit and bark, etc. Both the avocado and mango appear much more susceptible at flowering time, especially if high humidity and heavy dews or rainy weather prevail.

The remedial treatments most commonly suggested for the control of this disease are those sanitary measures designed to prevent infection. The following measures are recommended (a) maintenance of a clean orchard—infected limbs being pruned out and burned; (b) frequent spraying with Bordeaux mixture, especially at flowering time; (c) frequent disinfection of pruning tools and treatment of wounds with lead paint, Bordeaux paint or other disinfecting wound preparations, as seals; (d) avoiding injury to the fruit and to the bark of limbs and trunk by ladders and implements; (e) frequent inspection of trunk and limbs for early infections of bark canker; (f) when bark canker is located on large limbs or trunk, cut away infected bark to healthy tisue, disinfect and coat with disinfectant paint or other seal to prevent reinfection until nature heals the wound by the gradual overgrowth of cambium; (g) for prevention of sunburn of limbs and trunk, which seems to favor canker, the advisability of spraying the exposed parts with a protective coat of whitewash as is done with apple trees in the dormant season, might be considered.

Dr. Baldwin has observed that where avocado fruits hang in such a position as to come in contact with other fruit or branches a black rot spot results in a great many instances. He has reported it as economical to prevent such contacts by removing small branches and rearranging the natural "hang" of the fruit. In spite of the fact that this rather laborious procedure must often be done over again, following heavy winds, he has found it a valuable supplement to spraying with Bordeaux mixture. The general restriction of the occurrence of black fruit spot to the point of contact of fruits with each other or with parts of the tree,

indicates that the fungus may be primarily a wound-invading organism, in contrast to the more aggressive parasitic fungi.

Avocado Blotch

Avocado fruit spotting or blotch as described by Stevens (2), pp. 17-21, resembles the avocado blast discussed by Smith (4). The avocado blotch is said to be caused by a species of the fungus known as Cercospora, while blast is caused by the same species of bacteria which causes citrus blast. Either one or both diseases may be present in Hawaii but they have not been properly identified. The following description is quoted from Stevens:

Blotch is a surface spotting of seedling avocado fruit which is most noticeable as the fruit approaches maturity. The first spots may occur when the fruit is less than half grown, after which a succession of spots will follow until the surface is nearly covered. Mature blotch spots appear as small, slightly sunken, irregular blotches on the surface of the fruit, usually black in color, but often showing short, white fungous growth at the centers.

Fully developed blotch spots may vary from one-eighth to one-fourth of an inch in diameter. The beginning of such a spot is indicated by a pale green area, showing one or more brown or black dots which are smaller than a pin's head. Gradually the pale green area becomes brownish to black in color, and eventually develops into an irregular sunken pit or spot which is typical of the disease. These spots may be scattered freely over the surface of the infected fruit, or several may merge to form irregular black patches. The spots are confined chiefly to the rind of the fruit, but more advanced stages may penetrate into the edge of the meat. The interior of a spot is composed of brown, spongy tissue made up of dead, collapsed cells of the fruit rind, intermingled with the dark-colored mycelium of the fungus. The disease is confined apparently to the fruit. However, in a few cases the fungus has been found in spots on fruit stems similar to those on the fruit.

Avocado blotch is said to be controlled by Bordeaux sprays as used for anthracnose or black spot.

Avocado Blast

The following description of avocado blast is quoted from Smith (4):

The fruit exhibited a marked cracking, which was the most severe near the blossom end. In addition to the cracking, definite brownish, or more often black, irregular or nearly circular spots were found which were situated near or surrounding a lenticel. The disease is superficial, being limited almost entirely to the rind. In the older spots the tissue about the lenticel has become torn and the margin appears somewhat elevated, as if ruptured. The spots are slightly if at all depressed. They are variable in size from the younger stages, when the beginning of the spot is just visible, to a mature spot that may measure from one-eighth to one-quarter inch in diameter, or even larger by the coalescence of several spots. The cracking of the fruit is believed to follow a severe spotting (infection) of the fruit, as this condition would allow the tissue to dry out.

The cause of the trouble, as has been indicated, has been found to be a species of bacteria that was first described as causing a spot on lemons known as "black pit."

Varieties are said to vary in susceptibility, Knight being most severely attacked and Fuerte very slightly.

Avocado Scab, Russet Fruit, Carapace

The three blemishes of fruit called avocado scab, russet fruit and carapace spot are characterized by a roughness of the skin of the fruit.

Avocado Scab:

Avocado scab may not occur in Hawaii. It affects both foliage and fruit. The disease is said to attack only young and tender growth. The injury to fruit is superficial, marring the appearance but not affecting the quality. Again quoting from Stevens (2):

> The spots (on the leaves) are generally small, circular to irregular in outline, and vary from one-sixteenth to one-eighth of an inch or more in diameter. They are purplish brown to dark in color and may appear scattered over the surface or several may grow together to form irregular areas. . . .
>
> On the young shoots, twigs and leaf petioles the spots appear darker and more elevated. . . . On the fruit occurs the same oval-shaped, raised type of spot that is found on the twigs. The spots may be scattered or clustered together to form an irregular scabby mass.

Avocado scab is said to be more prevalent in young plants in the nursery. Timely applications of Bordeaux mixture are reported to be beneficial as a control procedure.

Russet Fruit:

Russet fruit is variously attributed to mechanical abrasion of young fruits by the foliage. Thrips, mites and fungi have been mentioned as causes. Locally the russet blotches and bands of russeting or occasional "ring neck" apparently have not been satisfactorily explained. Much of this type of blemish appears to be due to foliage abrasion and other injuries when the fruits are small.

Carapace Spot:

Horne (5) has described a rough, cracked, superficial skin blemish which resembles a turtle's back. On account of this resemblance this blemish was named "carapace spot." The cause is undetermined but Horne suggested that this blemish may be due to slight skin injuries of the young fruit, which do not visibly scratch or break the skin.

Red Spider

The red spider, or leaf mite, is a troublesome pest of avocado foliage, especially in sheltered locations in the dry season. Defoliation as a result of red spider infestation permits sunburn injury of fruit, and besides, is harmful to the tree in reducing its vitality and possibly preventing normal bud formation and setting of fruit. Sulphur dusts or sprays and oil sprays have been found useful in checking this pest.

Conclusion

In conclusion, the local avocado disease situation may be summarized as follows: The anthracnose of leaf, fruit, branches and trunk is the most troublesome

fungous disease with which the grower has to contend. Frequent spraying with Bordeaux mixture, adjustment of fruit to prevent abrasion, and the maintenance of a clean orchard are the best means of control. Cankered or dead branches should be removed and burned as soon as they are detected. Cankered spots on the trunk should be cleaned out to undoubted sound bark and wood, disinfected and sealed with disinfectant paint, wax or tar; and possibly other measures taken to assist the closing of the wound. Pruning tools should be disinfected frequently and pruning wounds painted. Sunburn injury of fruit and branches should be prevented. It is thought that the choice of a locality with a deep, well-drained soil, adapted to the variety, will assist materially in insuring a vigorous growth, resistant to diseases.

Several additional diseases or blemishes described in other countries may occur here but they appear to be relatively unimportant and the sanitary measures used for anthracnose or black spot should also tend to control them.

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Java's Sugar Industry

By W. van H. Duker

Introduction

Anyone visiting the Dutch East Indies and particularly Java, will probably be most impressed by the enormous number of people everywhere, the quietness, order and cleanliness of the population as a whole, and the high state of agricultural development of the land. Van Dyke, in his book on Java, says:

> There is every sign of prosperity or at least of physical well-being notwithstanding the congested condition in many sections. The native is an excellent farmer; he spares neither himself nor his wife nor his children in keeping the crop growth at its maximum. They all work. The Dutch administration lends a powerful hand and early realized that the imposition of foreign ideas upon a country or a people is always a questionable proceeding. They are usually not suitable and often meet with native opposition for no other reason than that they are foreign. The Dutch have learned this from experience and are now disposed to accept local conditions. They are protecting the native and allowing him to develop along his own lines. They are not trying to change him into a Dutchman, they do not ask him to wear Dutch shoes, shirts or hats, but allow him to go his own way, barefooted and in sarong.
>
> His religion, customs and traditions are respected, he is protected in his land and helped in his agriculture and the Dutch government recognized from the beginning that the first item in the economic program is that the native shall have enough to eat and they have spent millions on the land to that end. Largely, perhaps by reason of this liberal and general policy in administration, the Dutch have proved themselves the most successful colonial administrators of modern times.

The island of Java is situated between the 5th and 8th degrees south latitude and the 105th and 114th degrees east longitude. The area is 48,688 square miles and the present population is around 40,000,000 with an annual increase of 260,000.*

History

The finding of a sea route to the East Indies in 1498 and the consequent shifting of trade routes had a stimulating influence on the cane sugar cultivation in Java. Soon thereafter, both the East and West Indies became the principal export countries for sugar, taking the place of countries around the Mediterranean Sea.

It is not known just when the sugar industry started in Java, but a Chinese traveller, who visited Java in the year 400, mentions the presence of sugar cane in Java as something that he apparently did not expect to find there.

The first Hollanders, who landed in Java in 1595, found sugar marketed at Bantam, brought in from near-by places. The entrance of the East India Company in the Orient opened up a new era. They, themselves, were not particularly

* The island of Hawaii = 4,015 square miles; the island of Oahu = 598 square miles. The total population of the Hawaiian Islands is around 350,000.

interested in the development of Java as a sugar-producing country, because their business was that of the trader, but they compelled the Orient in general and Java in particular to supply products which they could sell profitably in the European market.

For the next two centuries the sugar industry developed but slowly on account of the uncertainty of the demand in the European market, the frequent changes of administration, and the consequent differences in economic policies.

In 1830, an entirely different and rather unique system of agricultural production was introduced, known as the "cultural system."

According to old Java traditions, the sovereign was the owner of the soil, who gave it to the native farmer in exchange for a part of the returns as well as for a certain amount of compelled labor on roads, bridges, etc. The Dutch government reasoned that they had replaced the native sovereign and were, therefore, now entitled to the same privileges, and proceeded to force contracts upon the native farmers, whereby the latter were compelled to give up one-fifth of their rice land for the cultivation of products in demand on the European market.

With cotton, coffee, tea, etc., this was a comparatively simple affair, but with sugar it was different, and separate agreements had to be made for its extraction in sugar mills. At first only Chinese took it up, but after the profitableness became more generally known, the Europeans followed.

The sugar industry then developed at a rapid rate. With a production of 14,850 short tons in 1835, it reached 92,800 in 1868. The yield per acre increased from .9 ton to 1.85 tons.

However, on account of mismanagement and ill use of the native labor, political pressure in Holland, etc., the cultural system was abandoned in favor of free labor and open competition by law adopted in 1870, providing, however, for a gradual withdrawal of governmental interference with the industry, which was to cease altogether in 1892.

During the period following, that is, from the crisis in 1884 caused by the rapid increase of the beet sugar industry in Europe and the damage wrought by the Sereh disease, the sugar industry passed through a number of very trying years with a turn to the better after the signing of the Brussels convention in 1902, whereby all sugar-producing countries, with the exception of Russia, agreed to abolish the system of premiums and artificial protection of the beet sugar industry.

From that time on the development took a regular course, except for a short period in 1917, when, due to a lack of shipping facilities, the crop could not be moved.

TOTAL PRODUCTION OF SUGAR

	Short Tons	Area in Acres
1895	636,726	190,167
1900	818,683	224,527
1905	1,143,096	260,807
1910	1,408,330	312,011
1915	1,450,996	372,773
1920	1,698,315	384,869
1925	2,530,003	440,787
1928	3,284,708	

The present crop is estimated at between 3,355,000 and 3,465,000 short tons.

Cane Culture

The total area of cultivated lands on Java is 10,002,680 bouws, or 17,504,690 acres, of which 4,511,405 *bouws* are *sawahs* of rice fields and 5,491,275 *bouws* non-irrigated lands. The area occupied as cane land was gradually increased:

1840	78,165	acres
1850	87,679	"
1860	98,396	"
1870	94,808	"
1880	112,086	"
1890	129,859	"
1900	224,527	"
1910	312,011	"
1920	384,869	"
1929	479,558	"

But even today the area in cane is but 5½ per cent of the total irrigated area of Java. Except for a small area which depends on rainfall (*tegallans*), the entire Java cane crop is grown on irrigated lands. The land itself is rented from the natives under voluntary agreement and for periods limited by governmental decree, with the general restriction that no more than one-third of the total *sawah* or rice area may be in cane at any one time. The rental has gradually increased, as may be seen from the following statistics taken from the annual report for 1928 of the General Syndicate:

1916	\$ 9.16 per acre
1920	14.64 per acre
1927	19.41 per acre

water included. The rotation runs more or less as follows:

September first year	finish of cane harvest
September first year to November first year	secondary products which require but little irrigation—beans, peanuts, etc.
November first year to April second year	rice crop (west monsoon crop)
April second year to November second year	secondary products
November second year to April third year	rice crop
April third year to September fourth year (about 17 to 18 months)	sugar cane

As soon as the last rice crop has been harvested, the plantation administration takes charge and begins with the first field operations, which consist of opening up the soil. During the west monsoon the fields have been saturated with water and in order to make it suitable for cane growth the soil must be exposed to the sun and reoxidized.

To do so, a system of soil treatment introduced by a Cuban, Alvaro Reynoso, is used, which is as follows: First a main ditch is dug to drain the soil, which

ditch is used later in the season as a supply ditch for irrigation water. The field is then divided into plots of one-fifth to one-sixth of an acre by secondary ditches. In these smaller areas plant furrows are dug, generally about 30 feet long, 1 foot deep and at a distance of 4 to 5 feet from center to center. The soil is piled up on the side and between the furrows. It is very important to have this opening of the soil done quickly, that is, immediately after the rice is off, because the new cane crop must have reached a certain growth and root system by the time the heavy rains start in. An abundance of labor is therefore required during this period, and this is not always available, particularly in years when the rice crop has turned out well, because as long as the average Javanese has any cash money at all he prefers rest to work.

As soon as the soil is sufficiently oxidized, the cane is planted, as a rule not later than July. The bottom of the furrow is loosened up and the cane seed laid down at measured distances and with the buds to the side, covered with soil and irrigated as required, generally from 4 to 5 days later. Either at the same time or a little later, doses of ammonium sulphate are applied to each individual plant. The greatest care is taken to bring the young cane to an even stand, and in going over a young plant field you see bamboo sticks placed next to the poor stool to show the spot where a seed had not sprouted and where a new seed piece has been planted, demanding special care and attention as to fertilizer and water.

As the cane grows, the soil which was piled between the furrows is gradually put back so that within two or three months the cane rows are level with the original field again and a little later, as more soil is supplied, the cane stands on a bank or hill, which offers opportunity for drainage. The soil as a rule is of a compact, clayish type, and standing water is harmful for the root system.

Plant Material: Soon after the outbreak and spreading of the Sereh disease, it was found that crops of healthy cane could be grown if the *bibit* was brought in from separate *bibit* plantations situated at a higher altitude. Such a procedure is naturally a very costly one, but with the newly developed P. O. J. varieties, seed can be taken from plantation-grown *bibit,* and the percentage of this source of *bibit* is increasing rapidly:

	1912-13 Per Cent	1919-20 Per Cent	1927-28 Per Cent
Topseed	59	41	23
Plantation *bibit* fields	2	28	57
Mountain *bibit*	39	31	20

Incidentally, where the cost of *bibit* obtained from mountain *bibit* fields varied from \$34.00-\$60.00 per acre, the present cost for *bibit* of P. O. J. 2878 is around \$11.00 per acre. This new variety occupied 12½ per cent of the cane area in 1927, 66½ per cent in 1928, and well over 90 per cent in 1929.

Cost of Operations: As far as individual earnings in the field are concerned, little information is at hand. As a rule, all the lighter operations, such as hoeing, irrigating, fertilizing, are given out in small contract or task work. How much a man makes depends, of course, on the amount of work done, but many of the natives consider the work in the cane field as a kind of side issue. If they run

short in their requirements for their daily support, they put in a few hours' work in the fields, which are always near their homes. The individual working time varies from one to ten hours per day.

For coolies doing the digging of furrows, the average pay runs from $0.22 to $0.40 per day, while for the lighter operations and about six hours' work per day, it will run between $0.14 and $0.18. The writer does not know that the following figure represents an average, but the figure of 300 work days was given as the one required to cultivate and harvest one acre.

Field Administration: Each cane field is a more or less administrative unit, with a *mandoer* (native overseer) in charge, who has under him several temporary assistant *mandoers*. Much of the lighter work, such as assorting of plant material, irrigation, hoeing, fertilizing and hilling up, is exclusively done by women under the direct supervision of woman *mandoers*. As it often happens that a large field is not planted all at the same time, several operations may take place in different parts of the field at the same time, so that much supervision is required.

The direct administration is done by the *mandoer* and controlled by a European overseer, who may have charge of an area of some 500 acres. The cane fields in Java do not form an unbroken unit, due to the peculiar land laws and compelled rotation of crops. A plantation of 2,625 acres has its fields scattered over an area of some 8,000 acres. The European overseers travel in light automobiles to and from the fields, but their actual field work or inspection of row for row is done on foot. No horses can be used in these fields, or gardens, as they are called. In fact, the entire cultivation is more horticulture than agriculture.

The labor is paid off in the field every day, or every other day, with the European overseer responsible for the detailed administration and cost accounting of each operation and field. He also conducts the negotiations with the natives for the rental of this specific cane area.

The plantation manager receives verbal reports of all operations at a certain fixed hour every day, generally at 6:30 p. m., when the entire plantation staff gathers at the plantation office for that purpose. After this report the native *mandoers* receive their orders for the next day's work from their respective section overseers.

Irrigation: On Java, the entire water supply is the property of the government and under its direct management.

The government adheres to the principle that in the east monsoon, or dry season, the cane crop has the preference in the regions assigned to the sugar interests by an official governmental franchise, but that in the west monsoon, the water goes to the native farmer for the growing of foodstuffs.

Therefore, towards the end of October and in November, the cane lands receive no water, even in dry years, and an early rainfall in the last months of the east monsoon is a big factor in the yield to be expected from the growing crop.

Experiments have shown that the yield of a well-started field may be decreased by as much as 1½ tons sugar per acre, if water is withheld in October or November.

To grow 1 K. G. rice about 9 M^3 water are required; for the same quantity of sugar, only 1 M^3 is needed.

Since the supply and distribution of the water is of such immense importance to the industry, the plantations have spent large sums of money to that end. But it is also clear that every cent spent in this direction is of direct benefit to the native population. They profit in two ways. In the first place, they obtain a higher yield (the yield of rice per *bouw* is about double on irrigated areas when compared with *tegallans* or dry lands), and in the second place, they profit on account of the increase in the minimum rentals to be paid for the use of their land.

The sugar industry pays for the supervision of the water distribution as well as for the construction of new irrigation works, extension and upkeep. In the latter case, as a rule, it is three-eighths of the total cost.

During the time period 1915-1924, the sugar industry paid fully 7½ million dollars as its share in the upkeep and extension of the irrigation system.

Harvest: An elaborate system of ripeness determination is in the hands of special field chemists. The results of these determinations form the basis of the harvest schedule. Very seldom the entire field is cut from one end to the other; more frequently a patch here and there is taken, perhaps of only one or two acres. Such practices are possible here because no ratoons are grown, and a very close check is kept that the entire stalk is actually dug out and not cut.

The increase in yield during recent years is well illustrated as follows:

TONS SUGAR PER ACRE (STANDARD MUSCOVADO)

1928	1927	1926	1925
7.07	5.97	5.17	6.02

The following detailed tabulation shows that 51 per cent of the plantations produced more than 7.13 tons sugar per acre:

Short Tons Sugar Per Acre	— Number of Plantations — 1928	1927	1926	1925
2.68 — 3.12	....	1	3	....
3.12 — 3.57	....	1	6	1
3.57 — 4.01	....	2	13	6
4.01 — 4.46	1	3	28	3
4.46 — 4.90	2	10	30	9
4.90 — 5.35	2	24	31	24
5.35 — 5.80	5	31	28	31
5.80 — 6.24	18	47	15	40
6.24 — 6.69	28	26	10	27
6.69 — 7.13	32	18	10	15
7.13 — 7.58	33	8	2	10
7.58 — 8.03	24	5	....	8
8.03 — 8.47	17	1	1	....
8.47 — 8.92	9	1	....	1
8.92 — 9.37	6	1	....	....
9.37 — 9.81	1	....	....	....
9.81 —10.26	1	....	....	....
	179	178	177	175

Manufacture

Most of the factories are making a white plantation sugar either by the sulphitation or the double carbonation process. They make the following assortments:

Superior head sugar (S. H. S.), a product of crystallized sugar, as white as possible and at least equal in color to No. 25 D. S.

Superior soft sugar (S. S. S.), a fine-grained white sugar, at least equal in color to No. 25 D. S.

Head sugar 16/h., also called European assortment, a light-colored, crystallized sugar corresponding in color to No. 16 D. S. and a polarization of at least 98°.

Muscovados, or American assortment of the color numbers 12, 13 and 14 and 96.5° polarization.

Molasses sugars in the numbers 8 and higher.

The cane is transported to the factories in bullock carts, or by rail, but in either case it is absolutely free from trash or tops and piled in neat bundles of from 10 to 15 sticks.

The mill itself, with tile floors and of the low one-story type, is scrupulously clean, well lighted and ventilated. Having seen many of them in different parts of the country, the following points are mentioned as most outstanding:

The growing interest in preparatory machinery, such as shredders and knives.

The different types of top roller surfacing not only the first mills, but the third and fourth mills as well.

The long and heavy carriers between the mills.

The advantage of driving each mill by a separate engine.

The almost universal use of electric power to drive auxiliary machinery and pumps.

The utter cleanliness and the perfectly quiet running of engines, which by no means were always of the latest type.

The automatic and sometimes electric juice scales.

The universal use of vertical juice heaters.

The general adoption of the double carbonation system in favor of sulphitation.

The close control on the boiling process and the use of projector screen to examine the grain in the pan.

The universally adopted system of double purging.

The detailed chemical control and the fact that the chemist spends most of his time in the factory with a native assistant in the laboratory operating the calculating machine.

The universal use of the metric system.

The thoroughness and uniformity of their work and the close cooperation with, and the strict adherence to, instructions given by the technical division of the Experiment Station.

The total recovery of around 85 per cent from juices of 83.85 purity.

Export and Cost

Up to the year 1870, practically the entire Java crop was exported to Europe, principally to the refineries in Amsterdam. After the change to the free sugar culture, England became the chief customer. Around 1900, this market was practically lost due to the protected beet sugar, and America, China and Japan formed the principal outlets next.

After the loss of the American market as a consequence of the Spanish-American war, Java's sales became more and more concentrated on British India and China in the form of white sugar, and by selling direct instead of through refineries in Hongkong and Japan.

The total sugar production for the world runs in the neighborhood of 25 million tons, two-thirds of which is cane sugar. Of this, Java furnishes around 14 per cent.

The chief competitor of Java is Cuba, to the extent of the quantity produced in excess of what America consumes. Next to this country is Formosa, with a rapidly increasing and energetically managed sugar industry bound to enter markets which at present are Java's main outlets.

The cost of production in Java at present varies between f10.00—f12.00 per quintal, or 1.81—2.17c per pound.

The cost of manufacture proper, including salaries, supplies, fuel, wages, bags and transportation to shipping port, f3.00—f3.50 per quintal, or .543—.63c per pound.

The average price received in 1928 varied between f13.00—f14.00 per quintal, or $47.00—$51.00 per ton.

The cost of making white sugar is from f0.75—f1.00 more than that of raw sugar.

The financial returns of the sugar companies are often misunderstood or misrepresented, due to the fact that most of the improvements have been paid for out of profits, while the dividends are generally expressed on the original capitalizations, which were usually small.

Organization

The Java sugar industry is well organized.

The General Syndicate was organized in 1894 and at present 174 of the 179 enterprises belong to it.

Its aim is to further the interests of the industry in a general sense, and deals with problems of taxation, land rent, irrigation, etc. In 1907, the Syndicate was appointed as an official committee of advice to the government in all matters relating to the sugar industry in the Dutch East Indies.

The Experiment Station was first organized in 1885 and has gradually grown to an institution with three main departments, agricultural, technological and engineering. The permanent staff consists of about 45 Europeans, 10 Chinese and 250 natives. In addition it employs 15 European local agents or group advisers in the extension service of the agricultural department.

The Experiment Station has built, at Pasoeroean, 34 houses for the European staff, who are also entitled to free medical treatment and a six months' leave for Europe after five years' service, with free fare and full salary.

The *Archief* for the Java sugar industry is a weekly publication edited by the Experiment Station and devoted mainly to the scientific side of the business.

The Java Sugar Employers Association was founded in 1920. This organization, with which 160 enterprises joined, deals with all questions relating to labor and is the outcome of the labor difficulties and disturbances in 1920.

The three above-named organizations have their own officers but the same president, in whose hands, therefore, rests the general direction of these central organizations of the industry.

A fourth organization is the United Sugar Producers Association of Java. This organization, with its headquarters in Holland, is represented in Java by a committee and a board of advisers. It sells the sugar produced by its members on a cooperative basis and handles fully 90 per cent of the total production.

Another organization is the Association of Owners of Sugar Estates, who reside either in Holland or elsewhere in Europe. They exchange views on, and discuss, questions relating to the sugar trade, and further its interest in a general sense.

The Pension Fund for employees, which provides for a pension for all employees at the age of fifty years, engaged by any of the member plantations, requires no premium to be paid by the employee, but demands that he spend 5 per cent of his salary on an endowment policy which is due at the time the pension is granted.

The Accident Fund has as its aim the lessening of the *risico* for the European and native employee.

The Bouricius Fund supplies support in case of sickness or unemployment and also provides for financial assistance to anyone in need of it who has contributed in some special way to the interest of the sugar industry.

The Royalty Association is a new institution which has opened the way to pay a royalty to those who have occupied themselves with cane breeding and who have developed a new and superior cane variety.

The Association of Employees is a trade organization with 1,800 members, has its own periodical, and is recognized by the General Syndicate.

The Culture Police is an organization under governmental control but paid for by the planters; it was established to furnish particular protection on the plantations against cane fires, thefts, etc.

The European personnel on the plantation receive, besides their salary, a definite share in the yearly profits of the company on a percentage basis, varying from 5 to 10 per cent, according to specific arrangements and position held. Their time of employment is limited, generally not over 20 to 25 years, but in this period they are dismissed or systematically promoted from cane scale employee to factory chemist, superintendent, field overseer, and finally to either head employee or plantation manager.

The plantations, in groups of five or six, maintain well-equipped hospitals, where free medical attendance is furnished to the laborers and their families.

Some of the plantations have established a plantation trade school open to boys of the ages between 10 and 14, where simple mechanical drawing and the making of plantation tools are taught.

As a conclusion, it might be said that Java is absolutely a garden island, and in summing up their accomplishments in industry and administration, they do things as they ought to be done, under the prevailing conditions.

We do not quite agree with those who are of the opinion that only cheap labor made this possible.

We may not be able to adopt their methods because each country has its own problems and pecularities, but we should consider that forethought and wise administration made it as it is. We may not be able to feed our cane plants with a spoon, but it will pay, even in our case, to give more attention to seeing that the fertilizer is applied where the cane roots are able to get it.

Cheap labor is only possible as long as cheap food is obtainable; and an abundant rural population only as long as their land holdings are kept intact.

No administration of 40 million natives by 175,000 Europeans is possible unless the laws are enforced. The ultimate happiness and well-being of the people have no relation to the language they speak, and therefore in the rural schools the Javanese children are taught their native language, and the more educated European is compelled to learn the Javanese and Malayan languages, since they are universally used in dealing with the population.

And it is not far from the truth to state that the reason for the unusual development of the island of Java lies in the fact that it has been governed and managed for centuries by a nation which forever had to struggle with its limited resources in its home country, that had to protect its very soil from being overrun by the ocean, and that could afford no waste of land or material.

Clarification and Its Influence on the Refining Qualities of Sugar

By H. F. Bomonti

Within the past few months, an opportunity was given the writer to investigate the factors responsible for the poor clarification and the poor refining qualities, particularly filtration efficiency and color, of the sugar produced by the Hamakua Mill Company.

Clarification Equipment

Hamakua Mill Company is one of the two factories in the Territory using the Petree Process. The clarification equipment used in this process consists of two Dorr clarifiers. The one known as the primary Dorr has four compartments and a capacity of 2000 cu. ft. The other, known as the secondary Dorr, has three compartments and a capacity of 1600 cu. ft.

The Dorr clarifier itself is a circular steel tank with a fairly flat conical bottom and a parallel conical top. Its interior is divided into a number of comparatively shallow compartments by trays also conical and parallel to the top and bottom. These compartments are separated completely except for the central opening, which extends from the top to the bottom. This forms what is called the mud passage and is common to all compartments. The mud-moving mechanism consists of a vertical shaft which is suspended from a truss on top of the clarifier and passes through the feed well and all the compartments to the bottom of the tank. Attached to this shaft, one just above the bottom of the tank and one just above each of the trays, are the scrapers extending to the side wall of the tank. The mud-moving mechanism is revolved very slowly and pulls the mud to the center well or mud passage.

Just beneath the cover of each compartment at uniformly spaced circumferential points are the clear juice overflow pipes. In each compartment, considered a settling unit, the overflow points are all connected to a header. There are as many take-out pipes for clear juice as there are compartments in the clarifier. The clear juice headers extending from the compartments are connected into an overflow box near the top of the apparatus. Each outlet pipe has a sliding sleeve, thus making it possible to adjust the amount of juice overflow from each compartment.

The mud accumulating in the bottom of the Dorr is withdrawn by a diaphragm pump as rapidly as it forms.

The Petree Process

The system of handling the juices and muds in this process is as follows:

The crusher and first mill juice and also the clarified from the secondary Dorr make up what is called primary juice. This juice is limed, boiled, and sent to the primary Dorr. The mud from the primary Dorr is then mixed with the second mill

juice and after liming and heating, this is sent to the secondary Dorr. The mud from the secondary Dorr is diluted with third mill juice and this is applied to the bagasse blanket behind the first mill.

The primary and secondary juices are limed continuously by a Petree-Dorr liming device. Usually, the primary juice is limed to 8.2—8.3 pH and the secondary juices to 7.3—7.5 pH. One of the objects in reducing the pH of the secondary juice is to keep the volume of settlings from the secondary Dorr at a minimum. When too large a volume of settlings is returned to the bagasse blanket, the extraction of juice from the cane is appreciably affected. Besides this, there would be a tendency for more of the fine suspended matter in the settlings to be returned to the second mill juice.

Theory of Clarification

From our clarification studies a number of years ago, the theory was advanced then that under normal conditions a definite quantity of phosphoric acid was required in juices before a satisfactory clarification could be secured. The phosphate in the juices is precipitated as some form of insoluble calcium phosphate. This precipitate is very flocculent and presumably entangles the finely dispersed matter, removing it from the solution. This view of the mechanism of clarification has been quite widely accepted.

There is another phase of clarification which has not been considered in the past but must be recognized in studying the clarification problem of Hamakua. Our original recommendations for good clarification specified a minimum concentration of 0.03 per cent phosphoric acid as P_2O_5. This means that with such an amount of phosphate sufficient precipitate would be formed to entangle all the coarser dispersed particles, leaving a fairly clear juice. However, it is logical to reason from this assumption that a given quantity of calcium phosphate precipitate can entangle only a certain amount of insoluble impurities. In other words, there must be a limit to the clarifying power of this precipitate. If the amount of insoluble impurities exceeds this limit then additional P_2O_5 would have to be provided to produce a well-clarified juice, otherwise the juice will be murky. The extent of the murkiness will depend on how deficient any juice is in P_2O_5 for the quantity of insoluble impurities to be removed.

Experimental Data

A number of clarification experiments were conducted on both primary and secondary juices to determine whether these juices behaved in the same way as other juices when limed to various reactions, then heated to boiling and allowed to settle. We also wanted to determine whether the maximum clarity was secured at reactions considered the optimum for increase in purity. Tests were made to determine the availability of the phosphates in juices. There is some reason to believe that phosphoric acid can exist in an insoluble form in the suspended matter which would be determined by our method for determining P_2O_5 but actually would not combine with calcium because it might have a greater affinity for this other element and therefore would not produce any clarifying effect. Experiments were also conducted to determine the minimum quantity of P_2O_5 that had to be added to the primary and secondary juices to effect a satisfactory clarification.

Two preliminary clarification series were made on primary juice (crusher and 1st mill juice only) and secondary juice consisting of 2nd mill juice. At the time these samples were taken, no mud was returned to the bagasse blanket. Portions of each juice were limed with varying quantities of lime, heated to boiling and allowed to settle on a steam bath. After settling, the clear portion was decanted and tested for pH and turbidity. The results follow:

PRIMARY JUICE

Cane D 1135 Field—Paauilo 1
Brix—13.3 P_2O_5—.0125 Per Cent

	pH of Clarified Juice	Turbidity
Raw Juice	..	..
Clarified Juice	6.8	2.0
" "	7.5	3.0
" "	8.0	3.5
" "	8.3	3.5
" "	8.3	3.5

SECONDARY JUICE (NO MUD RETURNED)

Cane D 1135 Field—Paauilo 1
Brix—5.0 P_2O_5—.005 Per Cent

	pH of Clarified Juice	Turbidity
Raw Juice	..	1.0
Clarified Juice	6.6	1.0
" "	7.0	1.0
" "	7.7	1.1
" "	8.2	1.7
" "	8.2	1.8

The pH values of the clarified juices are nearer to the pH of the hot limed juice because in these tests the temperature of the juice was not maintaind at or near 212° F. and the time of settling was considerably less than in actual practice.

From the above data it will be noted that the clearest juices were secured at the higher pH values. This confirms our previous findings and shows that no improvement in clarity can be expected by reducing the pH of the limed juices. The primary juice without the addition of secondary clarified juice gave a good clarification considering the low phosphate content. Later experiments will show that when the secondary clarified was added to crusher and first mill juice in the proportion of 1 to 2, the clarification was less satisfactory.

The secondary juice without primary settlings and without returning secondary settlings to the mill was very murky after clarification. With such a low phosphate content it is extremely doubtful if there was any precipitation of phosphate. From other clarification data we find that an amount such as this will usually remain soluble in alkaline solutions. For this reason we cannot expect much of a clarification.

The next clarification series was on secondary raw juice but without the addition of primary mud. However, when this sample was taken secondary mud was being returned to the bagasse blanket behind the first mill. On another sample of secondary juice taken in the manner just mentioned, the writer thought that it was abnormal because it contained such a large amount of suspended matter. It was possible for a shot of mud getting into the second mill juice in case there was a choke in the crusher which would leave a space in the bagasse blanket. For this reason care was taken when sampling the juices to be sure that the mill was operating in the usual way. In this clarification series purities were determined on all samples, including the raw juice both before and after filtration through kieselguhr. On two portions, small amounts of phosphoric acid were added to find out whether a satisfactory clarification could be secured. These juices were then limed to a suitable pH. The results of this clarification series follow:

SECONDARY RAW JUICE (WITHOUT PRIMARY MUD)

Cane D 1135	Field—Paauilo 1		P_2O_5—.0175 Per Cent	
	pH	Turbidity	Brix	Purity
Raw Juice	..	.5	7.75	76.13
Raw Juice after kieselguhr filtration	..	..	7.30	80.96
Clarified Juice	7.1	.5	7.80	79.75
" "	7.6	1.3	7.72	81.22
" "	7.8	1.4	7.75	80.40
" "	7.9	1.4	7.80	79.23
" "	7.9	1.7	7.82	80.30
P_2O_5 increased to .0375 per cent	7.6	2.2	7.57	81.11
P_2O_5 increased to .0575 per cent	7.6	4.0	7.51	79.63

Of particular importance in this series is the large change in purity after filtration with kieselguhr. In this case it amounted to 4.83 points in purity. From the appearance of the secondary juice, the writer would estimate that the suspended matter amounted to 1.5-2.0 per cent. This suspended material was very finely divided and quite free from cush-cush. The source of it is undoubtedly secondary mud washed out of the bagasse blanket, for when no mud was returned to the mill, the second mill juice appeared quite normal and free from this large amount of suspended matter. The second mill juice looked more like thin settlings than a low density juice.

Increasing the phosphate content of these juices to .04 per cent and .06 per cent brought about an improvement in clarity. But the quantities necessary for a satisfactory clarification (4.0 turbidity) are prohibitive. Further, the volume of settlings would be increased to such extent as to cause trouble at the mill. It is more than likely that increasing the volume of settlings returned to the mill would increase the amount of suspended matter which would be extracted from the bagasse blanket and returned to the secondary juice.

It has been contended that the addition of the primary settlings to secondary juice brought about a better clarification of this juice. The next clarification series on secondary juice with primary settlings fails to show any such indication:

SECONDARY JUICE WITH PRIMARY SETTLINGS

Cane D 1135				Field—Paauilo 5
	pH	Turbidity	Brix	Purity
Filtered Raw Juice	..	..	7.27	80.33
Clarified Juice	7.9	.5	7.86	79.01
" "	8.0	.5	7.80	79.23
" "	8.0	.5	8.09	78.00

It is very apparent in the above data that adding the primary settlings to the secondary juice and then proceeding with the clarification in the manner already described has not resulted in a clearer juice. Compared with tests conducted without the addition of the primary settlings, the turbidities are all definitely lower. While we have no information as to the increase in suspended solids necessary to reduce the turbidity from 1.0 to .5, the writer would venture the opinion that the amount is more than doubled. There are indications in these data that the purity of the juice is actually depressed due to the solution of some of the suspended

matter. Such an effect has been demonstrated in some early clarification studies conducted a number of years ago.

In view of the data presented so far on the clarification characteristics of secondary juice, the writer concluded that it would not be economically feasible or practical to attempt to improve the clarification as a whole by using treble superphosphate. The writer fails to think of any other place where the mud could be returned to the bagasse blanket without affecting the extraction. It is the writer's understanding that it is the consensus of opinion among users of the Petree Process that the mud should be returned to the mill as far forward as possible. Behind the first mill is as far forward as possible at Hamakua for the cane is not sufficiently disintegrated ahead of this to be in a suitable condition to adsorb the settlings. It would only result in further contamination of the primary juice and possibly without any beneficial effect on the secondary juice.

A number of clarification series were then conducted on the primary juice. As already mentioned, this juice consisted of a mixture of two parts of crusher and first mill juice and one part of secondary clarified juice. Judging from the Brix of this mixture and the Brix of the clarified juice as reported by the laboratory, this is approximately the correct proportion. Therefore, in all these experiments on primary juice this proportion was used. The first clarification series on primary juice was conducted to determine the turbidities and purities at various reactions. In two portions phosphoric acid was added in small amounts to define the minimum quantity necessary to give a satisfactory clarification. The procedure was the same in conducting these tests as that already described. The data for this test follow:

PRIMARY JUICE

Cane D 1135	Field—Paauilo 5		P_2O_5—.0125 Per Cent	
	pH	Turbidity	Brix	Purity
Raw Juice	..	..	11.35	81.85
Filtered Raw Juice	..	..	11.23	83.88
Clarified Juice	7.0	1.2	11.96	83.36
" "	7.4	1.7	12.01	83.68
" "	7.6	2.3	11.86	83.47
" "	7.7	2.8	11.64	83.85
" "	7.8	2.7	11.72	84.0
P_2O_5 increased .01 per cent	7.8	3.5	11.70	84.0
P_2O_5 increased .02 per cent	7.6	4.1	11.71	84.0

We have here the indication that the secondary clarified juice actually depressed the clarity of the primary clarified juice. In the first clarification series on crusher and 1st mill juices only, a maximum clarity of 3.5 was found. In this experiment the maximum clarity is 2.8 on the normal primary juice. The addition of .01 per cent and .02 per cent P_2O_5 to raw primary juice increased the clarity of this juice to 3.5 and 4.1, respectively. The increases in purity are rather small, which is characteristic of juices of this type, that is, with low phosphate juices. The maximum purity was found at the maximum pH on the normal primary juice but no difference was found in the purity of the clarified juices to which small amounts of P_2O_5 had been added to the raw juice. Both these purities were 84.0, or the same as the maximum for the normal primary juice.

Although several clarification series were made on primary juice to which small amounts of phosphoric acid were added to the raw juice, only the data from two are given because the results in the other series are practically the same. The data have been arranged in the following tabulation:

	PRIMARY JUICE				PRIMARY JUICE			
	Cane D 1135 Field—Paauilo 1 .0125 Per Cent—Original P_2O_5 Content of Juice .01 Per Cent P_2O_5 Added				Cane D 1135 Field—Paauilo 1 .015 Per Cent—Original P_2O_5 Content of Juice .015 Per Cent P_2O_5 Added			
	pH	Turbidity	Brix	Purity	pH	Turbidity	Brix	Purity
Raw Juice	..	..	12.1	83.4	..	..	13.1	82.3
Filtered Raw Juice	..	..	12.0	84.7	..	..	13.0	83.4
Clarified Juice....	6.7	1.2	12.6	84.0	7.0	3.3	13.6	83.4
" "	7.0	2.2	12.6	84.8	7.5	3.3	13.7	83.4
" "	7.5	3.0	12.6	84.8	7.6	4.2	13.5	83.6
" "	7.7	3.4	12.5	84.7	7.9	4.2	13.7	83.7
" "	7.8	3.2	12.4	83.8	7.9	4.3	13.6	83.1

From these data and others it became quite apparent that a very material improvement in the clarity of the juice could be secured by increasing the phosphate content of the primary juice .01-.015 per cent. In the laboratory experiments, there was no indication that the volume of the settlings would be increased to any great extent.

In view of these data, it was suggested that phosphoric acid be added to the juice going to the primary Dorr. This was added to the crusher juice in the form of a solution at the rate of 20 pounds of dry treble superphosphate per hour. A grinding rate of 30 tons cane per hour was assumed. The solution was made in a 50-gallon drum, 62.5 pounds of treble superphosphate being added per barrel. A valve mounted about 1½ inches from the bottom of the barrel was regulated so that the flow from the barrel would be at the rate of 10 inches out per hour. This arrangement is not satisfactory and the writer would suggest that an arrangement similar to the Petree-Dorr liming device be made which would then deliver a definite quantity of this phosphoric acid solution of a definite concentration every 15 or 30 seconds. Without doubt, this arrangement would be far more reliable and regular in its action than any hand-controlled valve, which needs almost constant attention. This experiment started on November 13, 1930, at 8:30 a. m. Samples of juice were taken at regular intervals from each compartment of the primary Dorr and tested for turbidity. The averages of the turbidity of the juice from each compartment for each hour have been tabulated below:

	Turbidities			
	Bottom Tray	2	3	Top Tray
November 13, 1930—				
8:30 a. m.— 9:30 a. m.	1.8	1.6	1.65	1.7
9:30 " —10:30 "	2.0	2.1	2.0	1.7
10:30 " —11:30 "	2.3	2.3	2.3	1.9
11:30 " —12:30 p. m.	2.4	2.6	2.5	2.0
12:30 p. m.— 1:30 "	2.3	2.5	2.4	2.0
1:30 " — 2:30 "	2.5	2.5	2.4	2.0
2:30 " — 3.30 "	3.1	3.2	3.0	2.4

November 14, 1930—				
9:00 a. m.	2.9	2.5	2.4	..
10:00 "	2.4	2.5	2.1	1.6
10:30 "	2.8	2.3	2.2	1.7
11:00 "	2.6	2.4	2.3	1.8

The turbidity figures for the first 5 or 6 hours on November 13, 1930, show a gradual improvment in the clarity of the juices through the addition of .013-.015 P_2O_5. With this type of a clarifier it would require several hours before all the juice is displaced. Nevertheless, the response was very positive. The turbidity figures themselves do not reveal the actual change in the appearance of the juice such as actually happened. According to G. F. Murray, who has had the opportunity to observe the clarified juices over a period of years, the improvement was quite striking. After continuing this experiment for a period of two days, there was no appreciable increase in the volume of the settlings from the primary Dorr. This confirms the observations in the laboratory experiments. The effect that this improved clarity had on the filtrability of sugar from "A" strikes will be discussed later.

Mention was made in the first part of this report that certain tests would be made to determine the availability of the P_2O_5 in the juices. By determining the P_2O_5 content on juices before and after filtration through kieselguhr we can form an opinion of its availability. Kieselguhr being chemically inert will not react with the phosphate actually in solution but will remove such material which is in coarse suspension. In a number of tests when the P_2O_5 content of the juices before and after filtration with kieselguhr was determined, no difference could be found. The conclusion, therefore, has been drawn that all the P_2O_5 in these juices was in solution and therefore in a form which could be precipitated as the insoluble calcium phosphate by the addition of lime.

Boiling System at Hamakua

The boiling system used at Hamakua during the 1930 crop was as follows:

Starting with a footing of seed in No. 2 pan, syrup is taken in until the pan is full, half is then cut over to No. 1 pan and this is completed on syrup making an "A" massecuite of 85-86 purity and yielding "A" molasses around 65 purity. The half remaining in No. 2 pan is completed on syrup and all is then cut over to No. 1 pan. This is then built up to 535 cu. ft. with syrup and finished with "A" molasses and remelt sugar, making a "B" massecuite of 75 purity, which yields molasses of 55-58 purity.

While boiling this "B" strike in No. 1 pan, No. 2 pan is started again as already mentioned, built up to 480 cu. ft. on syrup, half is cut over to No. 1 pan. More syrup is then taken in and finally remelt sugar and "B" molasses, making a massecuite of 70-74 purity, yielding molasses between 50 and 54 purity.

Since the factory started operations in November the two-boiling system advocated by this Station was followed. The "A" massecuites consisted of low-grade sugar for seed and syrup. The "B" massecuites were made of a cut from the "A" massecuites and remelt sugar and "A" molasses. The only reason this system is not followed continuously is on account of a lack of molasses storage capacity.

Filtration Test on Sugar

Three filtration tests were made on sugar from "A" strikes and four tests on sugar from "B" strikes prior to using phosphoric acid in the primary juice. After this treatment was started sugar from two "A" strikes and one "B" strike was tested. These results, together with other data taken from the laboratory records, appear in the table below:

BEFORE USING PHOSPHORIC ACID IN PRIMARY JUICE

	Massecuite			Molasses			Sugar	
	Brix	Pol	Purity	Brix	Pol	Purity	Pol	F.R. 20° C
"A" Strikes—	93.0	77.5	83.3	86.5	54.0	62.4	97.8	62.4
	93.0	77.5	83.3	86.0	52.4	61.0	98.0	69.0
	93.0	79.5	85.3	85.5	54.0	63.2	97.7	68.0
						Average	97.83	68.5
"B" Strikes—	95.0	72.0	75.8	92.6	46.3	50.0	96.9	34.5
	94.5	68.0	72.0	89.5	49.5	55.3	96.1	30.0
	95.0	72.0	75.8	92.5	45.0	48.6	96.7	35.0
	95.0	66.5	70.0	89.0	44.0	49.4	95.5	20.0
						Average	96.3	30.0

AFTER USING PHOSPHORIC ACID IN PRIMARY JUICE CLARIFICATION

	Massecuite			Molasses			Sugar	
	Brix	Pol	Purity	Brix	Pol	Purity	Pol	F.R. 20° C
"A" Strikes—	93.5	80.0	85.6	84.5	52.5	62.1	97.8	87.7
	94.0	80.6	85.7	86.5	54.5	63.0	98.2	89.7
						Average	98.0	88.7
"B" Strikes—	96.0	71.0	74.0	91.5	46.0	50.3	97.3	61.0

A comparison of the data on the "A" sugars produced before and after using phosphoric acid in the clarification of the primary juice shows a large improvement in the filtration efficiency of this sugar. The average filtration efficiency of the "A" strikes prior to this treatment was 68.5 at 97.83 pol, while the average filtration efficiency of two strikes after using the treatment was 88.7 at 98 pol, an increase of over 20 points. Sugar from four "B" strikes before the treatment gave an average filtration rate of 30 at 96.3 pol, while one strike after the treatment had a filtration rate of 61.0 at 97.3 pol. The full effect of this treatment could not be expected, especially in the "B" strikes, until it was in use for several weeks. Low grade sugar boiled prior to the beginning of this treatment is being used for seed and remelted and taken into the "B" strikes. This sugar, which undoubtedly is very poor filtering, contaminates the sugar made from better filtering material.

We are not in a position to run color determinations which would be comparable to Crockett's color figures at the present time. However, judging from the appearance of the sugar made after using phosphoric acid in the primary juice clarification, the writer believes that a material improvement was made.

CONCLUSIONS

In conclusion the writer believes that the poor clarification at this factory can be attributed to two factors: (1) The low phosphate content of the juice. (2) The large amount of impurities such as fine suspended matter, which is being washed out of the bagasse blanket and returned to the secondary juice. This results in a very murky secondary clarified juice, which in turn increases the load on the phosphoric acid beyond the limit of its clarifying power. The result is a murky clarified juice.

From the data on filtrability of sugar, is appears that a pronounced improvement can be made in this refining quality by increasing the phosphoric acid content of the primary juice .01-.015 per cent.

A decided decrease in color can be expected judging from the appearance of the sugar.

The writer was assisted by R. K. Hamilton of this Station.

ACKNOWLEDGMENTS

This opportunity is taken to thank R. M. Lindsay, manager of the Hamakua Mill Company, and G. F. Murray for their most generous cooperation.

Annual Synopsis of Mill Data

By W. L. McCleery

Operating data for the 39 factories of the Association for the year ending September 30, 1930, are given in this report. The sugar represented by these data amounts to 919,925 tons or an increase from the previous year of slightly over 1 per cent.

Data from eight factories include portions of the previous crop ground after September 30, 1929. Ten factories had not finished their 1930 crop at the close of the Synopsis year, September 30, 1930.

Factories are listed in the order of their average sugar production for the previous five seasons unless otherwise noted. Data for roller grooving and returner bar settings, omitted last year, have been included in the large tables. The order of recording surface grooves has been changed to conform to the usual practice. Data for factory equipment have been omitted this year as it is the intention to alternate this table with data on grooving and returner bar settings in following years. Roller pressures are given in tons per foot of roller in place of total tons as heretofore.

Varieties of Cane

Badila has increased to more than 1 per cent of the total tonnage thus bringing it into our major variety classification. This makes six major varieties against five in the two preceding seasons. H 109 has increased to 56.6 per cent and the percentage of Badila has more than doubled. Yellow Caledonia now makes up slightly less than 20 per cent of the total. Percentages of major varieties, except H 109 and Badila, have decreased materially.

D 1135 is the most widely distributed variety, being reported from 29 factories. H 109 is reported from 22, Yellow Caledonia from 21, and Yellow Tip from 15 factories.

Three-quarters of the tonnage listed as "Others" in Table 1, is accounted for in the minor varieties table. H 5909 and Manoa 213 appear in the minor varieties table for the first time. W 2 and K 73 have been dropped.

MINOR VARIETIES

One Per Cent or More of the Crop at Any Factory

K 107	.72	H 5909	.10
Uba	.67	McB. Seedlings	.07
P O J 36	.67	K 202	.06
H 456	.49	P O J 213	.05
St. Mex.	.29	Manoa 213	.04
U D 1	.24	W 4	.03
H 8965	.16	D 117	.03
Lahaina	.14	R B	.02

TABLE NO. 1
MAJOR VARIETIES OF CANE
(One per cent or more of total crop)

	H 109	Y. C.	D 1135	Yellow Tip	Striped Tip	Badilla	Others
H. C. & S. Co.	99	...	1	...	...	...	...
Oahu	95	...	3	...	...	...	2
Ewa	98	...	...	...	...	...	2
Waialua	97	...	1	...	...	...	2
Maui. Agr	95	...	...	...	...	...	5
Pioneer	97	...	1	...	...	...	2
Olaa	...	86	14	...	...	...	...
Lihue	52	...	5	12	...	15	16*
Haw. Sug	96	...	3	...	...	...	1
Honolulu	100	...	...	...	...	...	...
Kekaha	94	...	1	...	...	...	5
Onomea	...	81	6	11	...	...	2
Hilo	...	90	8	2	...	...	...
Haw. Agr	...	41	58	...	...	...	1
Honokaa	2	3	73	...	...	...	22†
Makee	54	16	...	15	...	6	9
Wailuku	95	...	3	...	...	...	2
Hakalau	...	79	6	14	...	...	1
McBryde	85	1	7	1	...	...	6
Laupahoehoe	...	24	58	17	...	...	1
Kahuku	96	4	...	...	...	...	...
Hamakua	...	8	81	11	...	...	...
Pepeekeo	...	93	3	4	...	...	...
Paauhau	...	1	71	16	...	...	12
Waiakea	...	96	2	...	...	...	2
Koloa	61	...	...	31	...	...	8
Hutchinson	...	44	54	...	...	...	2
Hawi	...	...	37	...	44	...	19‡
Honomu	...	91	7	...	...	...	2
Kaiwiki	...	11	84	3	...	...	2
Kohala	2	2	24	...	24	...	48§
Waimanalo	86	...	2	...	...	...	12
Kilauea	3	9	5	23	4	25	31¶
Kaeleku	...	100	...	...	...	...	...
Waianae	100	...	...	...	...	...	...
Union Mill	...	...	23	1	76	...	...
Niulii	...	18	38	24	20	...	...
Waimea	100	...	...	...	...	...	...
Olowalu	91	...	...	...	...	...	9
True Average 1930	56 6	19.9	12.3	3.5	1.6	1.2	4.9
" " 1929	53.1	21.5	13.0	4.3	2.1	.5	5.5
" " 1928	54.7	20.7	12.9	4.9	2.2	.3	4.3
" " 1927	53.1	23.7	11.8	4.0	1.6	.4	5.4
" " 1926	48.7	25.6	12.1	4.5	2.1	.5	6.5
" " 1925	42.7	30.7	11.9	2.7	2.1	.4	9.5
" " 1924	38.1	32.6	13.0	2.3	2.0	.5	12.5
" " 1923	30.7	36.3	11.2	1.2	1.6	.1	18.9
" " 1922	21.1	40.3	12.2	2.7	1.6	.2	21.9
" " 1921	15.0	45.1	11.0	1.2	1.8	...	25.9

* H 456, 8%
† Uba, 14%
‡ K 107, 11%
§ K 107, 43%
¶ Uba, 26%

K 107 leads the list closely followed by Uba and P. O. J. 36. The percentage of Uba has changed but little. K 107 and P. O. J. 36 have more than doubled. Striped Mexican has decreased to less than a half and Lahaina to less than a quarter of last year's figures. A large decrease in Rose Bamboo has almost eliminated this variety from the minor variety table.

Quality of Cane

We have had much poorer cane this season, the average cane pol having decreased from 12.90 to 12.49 and the first expressed juice purity from 87.18 to 87.04. These changes have increased the quality ratio a quarter of one ton bringing it to 8.83. This is poorer than in any previous year except 1927. There has been practically no change in the average fiber.

On Kauai the cane has improved in quality; on other islands it has been poorer. The quality on Maui has been poorer than in any previous season except 1923, and on Hawaii it is the poorest on record. The islands rank in the usual order, that is, Maui first, followed by Oahu, Kauai and Hawaii in the order named.

The improvement in quality on Kauai is attributable principally to better purity, although the cane pol also has improved slightly. The largest decrease in quality has been on Maui where decreases of almost .8 in cane pol, and over .5 in purity have reduced the calculated *yield per cent cane* by .78. Decreases in quality on Hawaii and Oahu amount to slightly over half of the decrease on Maui. The poorer quality on Hawaii is due principally to a decrease of .5 in cane pol, the decrease in purity being comparatively small. The decrease in cane pol has been smaller on Oahu, but a larger decrease in purity has depressed the quality of cane to approximately the same extent as on Hawaii.

If we had made these comparisons on the usual basis of quality ratio we would have formed a different and quite erroneous idea of the relative size of these changes in the quality. Figures for yield per cent cane and quality ratio, tabulated below, bring this out clearly. Both are calculated on the same basis except that quality ratios are reciprocals of yields per cent cane.

	YIELD % CANE			QUALITY RATIO		
	1929	1930	Difference	1929	1930	Difference
Hawaii	10.49	10.08	—.41	9.53	9.92	+.39
Maui	13.53	12.75	—.78	7.39	7.84	+.45
Oahu	12.20	11.78	—.42	8.20	8.49	+.29
Kauai	11.42	11.60	+.18	8.76	8.62	—.14

According to quality ratio, the decrease in quality on Maui has been slightly greater than the decrease on Hawaii; actually it has been almost twice as large. The decrease on Oahu according to quality ratio has been considerably less than the decrease on Hawaii and about two-thirds of the decrease on Maui; actually it has been about equal to the decrease on Hawaii and to a half of the decrease on Maui. The change in quality on Kauai, according to quality ratios has been a third as large as the change on Maui, while actually it has been less than a quarter as large.

Values for yield per cent cane are rational numbers for they represent direct

TABLE NO. 2

COMPOSITION OF CANE BY ISLANDS

	Hawaii	Maui	Oahu	Kauai	Whole Group
1921					
Pol	12.25	14.67	13.72	12.67	13.12
Per cent Fiber	13.28	11.82	12.40	13.28	12.80
Purity 1st Expressed Juice	87.18	87.37	85.46	84.07	86.22
Quality Ratio	8.98	7.51	8.11	8.76	8.41
1922					
Pol	12.07	13.95	13.61	13.03	12.97
Per cent Fiber	13.16	12.38	12.88	13.22	12.95
Purity 1st Expressed Juice	87.17	87.88	86.18	85.80	86.84
Quality Ratio	9.19	7.75	8.04	8.36	8.45
1923					
Pol	12.09	13.61	12.99	12.94	12.78
Per cent Fiber	13.14	12.01	12.86	12.99	12.82
Purity 1st Expressed Juice	87.61	88.65	85.52	86.58	87.05
Quality Ratio	9.12	7.91	8.50	8.42	8.57
1924					
Pol	12.44	14.34	13.48	13.34	13.26
Per cent Fiber	12.99	12.16	12.72	12.94	12.74
Purity 1st Expressed Juice	87.98	89.19	87.02	87.31	87.86
Quality Ratio	8.86	7.58	8.16	8.12	8.25
1925					
Pol	12.35	14.42	13.52	13.24	13.22
Per cent Fiber	12.92	12.40	12.60	12.91	12.74
Purity 1st Expressed Juice	88.02	89.36	87.11	87.19	87.92
Quality Ratio	8.92	7.47	8.18	8.21	8.28
1926					
Pol	12.53	14.66	13.40	13.03	13.24
Per cent Fiber	12.90	12.24	12.72	12.46	12.65
Purity 1st Expressed Juice	87.59	89.03	86.61	86.68	87.45
Quality Ratio	8.80	7.40	8.29	8.39	8.30
1927					
Pol	11.34	14.00	12.61	12.07	12.32
Per cent Fiber	12.84	11.98	12.29	12.65	12.49
Purity 1st Expressed Juice	86.27	87.85	85.87	85.17	86.28
Quality Ratio	9.81	7.76	8.86	9.19	8.99
1928					
Pol	11.57	14.13	13.09	12.09	12.55
Per cent Fiber	12.58	12.56	12.13	12.82	12.50
Purity 1st Expressed Juice	86.60	88.76	86.84	85.16	86.84
Quality Ratio	9.62	7.60	8.45	9.19	8.79
1929					
Pol	11.80	14.56	13.49	12.64	12.90
Per cent Fiber	12.53	13.24	12.28	12.61	12.62
Purity 1st Expressed Juice	86.65	89.14	87.17	85.97	87.18
Quality Ratio	9.53	7.39	8.20	8.76	8.57
1930					
Pol	11.30	13.77	13.05	12.67	12.49
Per cent Fiber	12.73	12.92	12.35	12.57	12.63
Purity 1st Expressed Juice	86.59	88.60	86.98	86.34	87.04
Quality Ratio	9.92	7.84	8.49	8.62	8.83

TABLE NO. 3

True averages of all factories except those using the Petree Process

	1925	1926	1927	1928	1929	1930
Cane—						
Pol	12.99	12.99	12.05	12.30	12.63	12.27
Fiber	12.80	12.71	12.55	12.47	12.54	12.62
Tons per ton sugar	8.45	8.50	9.24	9.03	8.75	9.00
Bagasse—						
Pol	1.54	1.58	1.50	1.53	1.55	1.51
Moisture	41.25	41.09	41.61	41.36	41.46	41.42
Fiber	56.55	56.64	56.20	56.42	56.31	56.41
Pol % cane	0.35	0.35	0.33	0.34	0.34	0.34
Pol % pol of cane	2.69	2.73	2.77	2.76	2.72	2.75
Milling loss	2.73	2.79	2.66	2.72	2.74	2.67
Weight % cane	22.63	22.44	22.33	22.11	22.26	22.37
First Expressed Juice—						
Brix	18.14	18.24	17.17	17.45	17.76	17.36
Pol	15.91	15.88	14.74	15.08	15.40	15.04
Purity	87.67	87.05	85.84	86.41	86.69	86.68
"Java ratio"	81.7	81.8	81.7	81.6	82.1	81.5
Mixed Juice—						
Brix	13.44	13.65	12.88	13.04	13.29	12.98
Pol	11.38	11.48	10.67	10.89	11.15	10.87
Purity	84.67	84.12	82.88	83.47	83.89	83.73
Weight % cane	111.03	110.10	109.71	109.87	110.18	109.77
Pol % cane	12.64	12.64	11.71	11.96	12.29	11.93
Extraction	97.31	97.27	97.23	97.24	97.28	97.25
Extraction ratio	21.0	21.5	22.1	22.1	21.7	21.8
Last Expressed Juice—						
Pol	1.90	2.06	1.88	1.94	1.99	1.94
Purity	69.63	68.72	67.76	68.39	68.73	68.54
Imbibition water % cane	33.66	32.54	32.04	31.99	32.44	32.15
Syrup—						
Brix	63.63	64.21	62.91	63.05	63.38	64.09
Purity	85.95	85.49	84.54	84.86	85.24	85.17
Increase in purity	1.28	1.37	1.66	1.39	1.35	1.44
Lbs. avail. CaO per ton cane	1.56	1.66	1.52	1.46	1.38	1.30
Press Cake—						
Pol	2.17	2.49	2.22	2.34	2.27	1.82
Weight % cane	2.45	2.63	2.67	2.87	2.87	2.96
Pol % cane	0.05	0.07	0.06	0.07	0.07	0.05
Pol % pol of cane	0.41	0.50	0.49	0.55	0.52	0.44
Commercial Sugar—						
Pol	97.23	97.29	97.40	97.49	97.64	97.66
Moisture	0.74	0.66	0.64	0.62	0.58	0.56
Weight % cane	11.83	11.77	10.83	11.08	11.43	11.11
Pol % cane	11.50	11.45	10.55	10.80	11.16	10.85
Pol % pol of cane	88.78	88.41	87.96	88.21	88.59	88.85
Pol % pol of juice	91.24	90.95	90.45	90.70	91.06	91.36
Deterioration factor	0.27	0.24	0.25	0.25	0.25	0.24
Final Molasses—						
Weight % cane	2.82	2.94	3.02	2.97	2.98	2.89
Sucrose % cane	0.93	0.99	1.01	0.98	0.98	0.94
Sucrose % pol of cane	7.20	7.63	8.37	8.00	7.77	7.67
Sucrose % pol of juice	7.40	7.84	8.60	8.22	7.98	7.88
Gravity solids	90.09	89.59	89.43	88.77	88.82	88.77
Gravity purity	36.97	37.62	37.40	37.41	37.13	36.69
Undetermined Losses—						
Pol % cane	0.16	0.13	0.11	0.11	0.09	0.08
Pol % pol of cane	0.92	0.73	0.41	0.48	0.40	0.30

measures of quantities; they are in simple arithmetical ratio to each other and therefore are directly comparable. As quality ratios represent tons cane per ton sugar they are reciprocals of yield per cent cane and are not rational numbers. They are not proportional to each other and it is not permissible to compare them directly.

Discrepancies discussed above illustrate well the errors involved in making direct comparisons of these reciprocal values. Notwithstanding these errors, tons cane per ton of sugar is used almost exclusively in Hawaii for comparing quality of cane and decisions are made on the basis of these comparisons which are not mathematically permissible. As figures for tons cane per ton of sugar can neither be averaged nor compared directly, discarding these reciprocal values in favor of yields per cent cane which are comparable would be a progressive move. We have been thinking so long in terms of tons cane per ton of sugar that the change may seem difficult, yet the difficulty should not be nearly as great as might be anticipated.

Chemical Control

The control is on a sucrose basis at 33 factories, the same number as last year.

The mixed juice is weighed at one additional factory bringing the total to 36, and the molasses is weighed at two additional factories, bringing the total to 30. Molasses weights calculated from measurements are reported from 7 of the factories, leaving two from which neither weights nor measurements are reported.

One factory only has failed to report any pH data against 5 last year. The pH of the limed juice has been reported from all but two non-Petree factories and in one instance only was the pH determined on the cold juice. This is a marked improvement over last year when 6 non-Petree factories did not report this figure and in three instances the determinations were on the juice before heating.

We would again note that Tables 4 and 5 are largely checks on the accuracy of the chemical control though data therein may disclose avoidable losses, that due to discrepancies in control methods recovery per cent available can slightly exceed 100 per cent and that the actual amount of molasses is considerably less than the calculated theoretical.

Referring to these tables we find a change in a tendency which has been noticeable for a number of years. Each season the number of factories reporting 100 per cent recovery or over on the calculated available has increased until this year, when the number has decreased. On the pol basis (Table 4) 25 factories have reported 100 per cent or over, a reduction of 3. Thirteen have reported 100 per cent or over on a sucrose basis (Table 5), a reduction of 2. On the other hand, the number reporting over 101 per cent has increased from 11 to 13 on the pol basis and from 2 to 4 on the sucrose basis.

The calculation of molasses produced on theoretical in Table 4 is based on the theoretical being the difference between gravity solids in the syrup and in the sugar produced, while the s.j.m. formula is used for calculating the theoretical amount in Table 5. There should not be very large differences between the two sets of figures in the absence of large errors in the control, hence their value in checking the accuracy of the control. Several years ago when these two sets of

TABLE NO. 4

APPARENT BOILING-HOUSE RECOVERY

Comparing per cent available sucrose in the syrup (calculated by formula) with per cent pol actually obtained.

Factory	Available*	Obtained	Recovery on Available	Molasses Produced on Theoretical†
H. C. & S. Co.	93.58	94.77	101.3	93.5
Oahu	92.58	94.39	102.0	90.3
Ewa	92.61	92.45	99.8	85.4
Waialua	91.60	92.41	100.9	90.1
Maui Agr.	93.36	94.91	101.7	98.6
Pioneer	92.44	92.21	99.8	93.0
Olaa	91.32	91.08	99.7	92.3
Lihue	90.75	92.08	101.5	87.3
Haw. Sug.	93.03	94.73	101.8	91.4
Honolulu	92.05	92.16	100.1	91.5
Kekaha	91.05	90.73	99.6	86.6
Onomea	91.90	92.40	100.5	92.2
Hilo	91.62	90.47	98.7	89.1
Haw. Agr.	90.96	91.37	100.5	93.8
Honokaa	90.13	90.16	100.0	91.2
Makee	88.82	88.42	99.5	87.4
Wailuku	90.73	91.60	101.0	93.5
Hakalau	91.82	93.02	101.3	91.3
McBryde	92.15	93.42	101.4	94.0
Laupahoehoe	93.42	93.42	100.0	89.8
Kahuku	90.39	93.08	103.0	91.7
Hamakua	92.27	91.68	99.4	99.6
Pepeekeo	92.14	92.40	100.3	93.7
Paauhau	88.80	87.79	98.9	89.0
Waiakea	90.15	90.33	100.2	87.6
Koloa	91.67	92.93	101.4	92.1
Hutchinson	91.85	93.26	101.5	89.0
Hawi	88.47	89.08	100.7	85.6
Honomu	91.48	92.62	101.2	94.4
Kaiwiki	89.10	88.43	99.2	87.9
Kohala	89.44	89.95	100.6	92.6
Waimanalo	87.96	88.99	101.2	89.4
Kilauea	84.98	83.87	98.7	91.7
Kaeleku	87.55	85.55	97.7	83.0
Waianae	90.93	91.27	100.4	82.7
Union Mill	87.28	86.73	99.4	91.2
Niulii	84.89	87.22	102.7	...
Waimea	90.29	86.74	96.1	...
Olowalu	89.71	88.96	99.2	85.2

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When moisture in sugar has not been reported, the moisture corresponding to 0.25 deterioration factor has been used. 38 has been used when the gravity purity of the molasses has not been reported.

† Gravity solids in syrup, less solids accounted for in commercial sugar considered as theoretical gravity solids in final molasses.

TABLE NO. 5

TRUE BOILING-HOUSE RECOVERY

Comparing per cent sucrose available and recovered

Factory	Available	Obtained	% Recovery on Available	Molasses Produced on Theoretical*
H. C. & S. Co.	93.58	94.17	100.6	89.6
Oahu	92.83	93.16	100.4	86.9
Ewa	92.88	91.49	98.5	90.6
Waialua	91.81	90.88	99.0	90.1
Maui Agr	93.19	94.64	101.6	92.8
Pioneer	92.40	91.57	99.1	95.7
Olaa	90.91	90.78	99.9	90.5
Lihue	90.93	90.85	99.9	85.3
Haw. Sug	93.02	94.17	101.2	86.0
Honolulu	92.35	90.93	98.5	97.5
Kekaha	91.09	90.24	99.1	89.8
Onomea	91.96	91.96	100.0	93.3
Hilo	91.33	90.19	98.8	92.6
Haw. Agr	91.18	90.24	99.0	96.0
Honokaa	90.14	89.65	99.5	92.7
Makee	88.98	87.20	98.0	90.5
Wailuku	91.03	90.61	99.5	94.1
Hakalau	91.79	92.55	100.8	88.4
McBryde	92.21	92.47	100.3	91.3
Laupahoehoe	93.34	93.07	99.7	91.6
Kahuku	90.68	91.67	101.1	86.8
Hamakua	92.03	91.68	99.6	101.5
Pepeekeo	92.09	92.22	100.1	94.6
Paauhau	88.66	87.29	98.5	92.2
Waiakea	90.27	89.37	99.0	89.1
Koloa	91.73	92.19	100.5	89.5
Hutchinson	91.73	92.78	101.1	84.5
Honomu	91.44	92.12	100.7	91.6
Kohala	89.54	89.30	99.7	93.0
Waimanalo	87.94	88.45	100.6	87.4
Kilauea	84.79	83.36	98.3	93.2
Waianae	90.91	90.31	99.3	82.0
Olowalu	89.47	88.63	99.1	87.3

* Calculated by S. J. M. formula.

TABLE NO. 6

GRAVITY SOLIDS AND SUCROSE BALANCES

Factory	GRAVITY SOLIDS PER 100 GRAVITY SOLIDS IN MIXED JUICE				SUCROSE PER 100 SUCROSE IN MIXED JUICE			
	Press Cake	Commercial Sugar	Final Molasses	Undetermined	Press Cake	Commercial Sugar	Final Molasses	Undetermined
H. C. & S. Co	4.2	81.6	13.3	0.9	0.52	93.68	5.75	0.05
Oahu	5.5	78.3	14.4	1.8	0.39	92.80	6.23	0.58
Ewa	6.8	75.0	15.5	2.7	0.38	91.14	6.45	2.03
Waialua	2.4	78.1	16.9	2.6	0.16	90.73	7.38	1.73
Maui Agr.	..	84.6	15.2	0.2	....	94.64	6.32	—0.96
Pioneer	5.0	76.2	17.4	1.4	0.29	91.30	7.27	1.14
Olaa	13.3	69.5	15.7	1.5	1.22	89.67	8.23	0.88
Lihue	3.7	76.0	17.3	3.0	0.38	90.50	7.74	1.38
Haw. Sug	4.0	80.3	14.4	1.3	0.16	94.02	6.00	—0.18
Honolulu	5.2	76.0	17.2	1.6	0.34	90.62	7.46	1.58
Kekaha	4.3	75.4	17.7	2.6	0.47	89.82	8.00	1.71
Onomea	4.2	77.4	17.2	1.2	0.19	91.79	7.50	0.52
Hilo	5.1	74.6	18.0	2.3	0.24	89.97	8.03	1.76
Haw. Agr.	3.3	76.8	18.4	1.5	0.30	89.97	8.47	1.26
Honokaa	5.9	72.8	19.5	1.8	0.58	89.13	9.14	1.15
Makee	4.6	70.4	21.4	3.6	0.46	86.80	9.97	2.77
Wailuku	6.8	74.4	17.5	1.3	0.63	90.04	8.44	0.89
Hakalau	3.8	77.5	17.1	1.6	0.18	92.38	7.26	0.18
McBryde	3.0	78.1	17.5	1.4	0.46	92.04	7.11	0.39
Laupahoehoe	3.3	80.1	15.0	1.6	0.10	92.98	6.10	0.82
Kahuku	5.2	73.2	19.5	2.1	0.31	91.39	8.09	0.21
Hamakua	..	79.8	20.1	0.1	....	91.68	8.09	0.23
Pepeekeo	6.1	75.4	17.6	0.9	0.36	91.89	7.48	0.27
Paauhau	5.3	71.3	20.7	2.7	0.50	86.85	10.45	2.20
Waiakea	4.4	73.6	19.0	3.0	0.58	88.85	8.67	1.90
Koloa	6.1	74.8	17.6	1.5	0.70	91.54	7.40	0.36
Hutchinson	6.3	75.3	16.3	2.1	0.19	92.60	6.99	0.22
Honomu	6.6	74.6	17.7	1.1	0.17	91.96	7.84	0.03
Kohala	5.7	72.6	20.2	1.5	0.77	88.61	9.73	0.89
Waimanalo	6.4	68.8	22.1	2.7	0.58	87.94	10.54	0.94
Kilauea	4.8	65.1	27.5	2.6	1.66	81.98	14.18	2.18
Waianae	3.8	75.3	16.9	4.0	0.93	89.47	7.45	2.15
Olowalu	6.7	71.2	18.8	3.3	0.49	88.20	9.19	2.12

Factory	Cane Sucrose*	Sucrose	Gravity Purity	Gravity Purity	Increase in Purity	Sucrose	Sucrose per 100 Sucrose* in cane	mined Loss per 100 Sucrose* in cane
H. C. & S. Co.	14.45	11.47	89.14†	89.11	—0.03	98.05	92.04	0.05
Oahu	13.63	11.94	87.15	87.86	0.71	98.41	91.02	0.57
Ewa	13.40	11.70	84.66	87.14	2.48	98.57	89.67	2.00
Waialua	13.54	11.94	86.5	87.2	0.7	98.55	87.58	1.67
Maui Agr.	14.63	12.18	87.92†	88.22	0.30	97.77	92.55	—0.94
Pioneer	13.57	11.89	84.99	86.40	1.41	98.27	89.43	1.12
Olaa	12.12	11.72	85.7	87.1	1.4	97.99	86.39	0.84
Lihue	12.79	11.37	85.1	85.7	0.6	98.09	88.22	1.34
Haw. Sug.	14.33	12.21	86.40	87.69	1.29	98.22	92.24	—0.18
Honolulu	13.79	11.81	86.58	88.2	1.62	100.0	88.19	1.53
Kekaha	13.32	11.41	85.06	86.14	1.08	98.20	87.65	1.67
Onomea	11.33	9.89	84.93	86.54	1.61	97.82	90.04	0.51
Hilo	11.24	9.87	84.49	85.47	0.98	97.37	87.91	1.72
Haw. Agr.	11.67	11.57	86.34	86.84	0.50	98.27	87.51	1.23
Honokaa	10.27	9.85	82.64	84.99	2.35	97.83	83.41	1.08
Makee	11.66	10.43	82.5	83.2	0.7	97.60	83.27	2.66
Wailuku	12.35	10.14	84.9	87.0	2.1	98.23	88.31	0.87
Hakalau	10.95	9.28	83.74	84.99	1.25	96.75	91.04	0.18
McBryde	13.13	10.94	84.89	85.70	0.81	97.92	89.73	0.38
Laupahoehoe	11.85	10.24	87.00	87.81	0.81	98.18	90.16	0.79
Kahuku	11.38	9.99	81.72	83.18	1.46	98.31	89.33	0.20
Hamakua	11.56	10.80	85.71†	85.82	0.11	97.93	88.05	0.22
Pepeekeo	11.54	10.68	83.49	85.86	2.37	98.12	89.66	0.26
Paauhau	10.94	9.33	83.01	84.73	1.72	97.53	84.36	2.13
Waiakea	12.04	10.63	83.97	84.88	0.91	97.88	85.36	1.82
Koloa	11.99	10.10	82.98	85.11	2.13	98.00	89.08	0.35
Hutchinson	12.16	11.15	83.53	85.06	1.53	97.45	89.95	0.21
Honomu	11.13	9.40	83.11	85.68	2.57	98.28	90.32	0.03
Kohala	10.88	9.36	82.32	84.57	2.25	97.49	85.94	0.86
Waimanalo	11.20	9.45	79.65	81.40	1.75	97.13	86.61	0.93
Kilauea	10.53	9.91	79.85	80.67	0.82	97.70	78.28	2.08
Waianae	13.61	11.94	84.20	85.26	1.06	97.66	87.57	2.10
Olowalu	13.04	10.67	82.36	84.25	1.89	97.01	86.52	2.08
‡True Average 1930	12.67	11.08	85.35	86.49	1.14	98.05	88.90	0.89
" " 1929	13.08	11.44	85.58	86.60	1.02	98.00	88.75	1.05
" " 1928	12.69	11.22	85.15	86.23	1.08	97.86	88.49	1.21
" " 1927	12.46	11.01	84.53	85.86	1.33	97.79	87.96	1.13
" " 1926	13.35	11.68	85.38	86.66	1.28	97.67	88.41	1.20

* Pol in bagasse and press cake has been assumed to be the same as sucrose in calculating sucrose in cane.
† Clarified juice. ‡ Refinery data from Honolulu not included in averages.

figures were first compiled there were wide variations between corresponding figures and also extremely high and low figures for production per cent theoretical. In recent years the results have been more consistent indicating improvement in the accuracy of the control. The yearly average molasses produced on theoretical in both Tables 4 and 5 is close to 90 per cent. Assuming that a difference of 5 on either side of 90 per cent of the theoretical in Table 5 should include all reasonably accurate figures, we find that 4 factories are above and 2 are below these limits, while in 1929, 5 factories were above and 6 below.

Table 6 contains gravity solids and sucrose balances for the factories reporting sucrose. Two factories have reported negative undetermined losses of sucrose though none have reported negative undetermined losses of solids. In both respects the above conditions are the same as last year.

Table 7 is a compilation of sucrose data from the 33 factories so reporting. These data represent 96 per cent of the crop, the same proportion as last year.

Undetermined losses on a pol basis are too low, chiefly though not wholly because sucrose in final molasses is used in making up the pol balance. Undetermined losses on the pol basis for factories included in Table 7 (sucrose basis) have again been averaged to determine the difference for all factories reporting on both bases. The difference this year is .84. By adding this figure to .14, the undetermined loss in the large table, we obtain .98 as the corrected average undetermined loss for 1930.

Table 3 is again given, with true averages for all factories except the three reporting on the Petree process basis. These data should be used when making certain comparisons rather than the averages in the first large table.

Milling

The average quality of milling work was about the same as in 1929, although we have had such unfavorable factors as a .4 decrease in cane pol and a 1.6 per cent increase in grinding rate. The extraction was 97.34 against 97.35 last year, and the extraction ratio 21.1 against 21.0. The milling loss improved from 2.72 to 2.63, this figure being a new record. Undiluted juice in bagasse per cent fiber, the figure used in Java for comparing milling results, was 21.8 for both years. A condensed table of milling data follows:

Year	Tons Cane per Hour..........	Tonnage Ratio.......	Tonnage Fiber Ratio..........	Tons Pressure per Linear Foot Roller.	Imbibition Water per Cent Cane.....	Milling Loss.........	Extraction Ratio....	Extraction..........
1922....	39.93	1.54	19.9	65.2	34.75	3.02	23.3	96.98
1923....	42.03	1.56	20.0	66.2	35.12	2.76	21.6	97.23
1924....	43.63	1.62	20.6	66.9	34.90	2.78	21.0	97.33
1925....	45.31	1.71	21.8	66.5	33.63	2.82	21.3	97.29
1926....	46.43	1.78	22.5	67.4	33.61	2.88	21.7	97.25
1927....	47.87	1.78	22.2	68.2	32.53	2.73	22.2	97.23
1928....	49.30	1.83	22.9	70.5	32.16	2.75	21.9	97.26
1929....	50.98	1.89	23.9	70.4	33.26	2.72	21.0	97.35
1930....	51.79	1.92	24.2	70.6	33.26	2.63	21.1	97.34

As mentioned earlier the grinding rate increased 1.6 per cent. This is the ninth successive yearly increase and the rate of grinding has increased nearly 42 per cent during the period. The average pressure per linear foot of roller increased from 70.4 to 70.6 tons, and while we have not had an increase in all recent years the overall increase for the nine crops that this figure has been averaged, amounts to 8 per cent.

Imbibition water per cent cane, 33.26, was the same as the previous year. The number of factories with increases and decreases were about evenly divided. The trend of this figure had been downward for the six crops preceding 1929.

Bagasse pol was the lowest on record, 1.49 against 1.54 the year previous. Lower figures than the year before were reported from two-thirds of the factories. Bagasse moisture was 41.25 against 41.24 in 1929. The plus and minus changes in moisture were about equally divided between the factories. The moisture averages just given are not the lowest on record, but are lower than for any year since 1921.

The difference in purity between first expressed juice and mixed juice increased to 2.96 from 2.80, a record low figure last year. The purity difference between first expressed juice and last mill juice also increased from 18.10 to 18.42. These purity differences are more or less influenced by mill sanitation and the amount of field trash accompanying the cane. Sanitation has been improving in recent years due to cleaner mills, faster grinding and the change in several factories to the use of unstrained mill juice pumps. We have reason to believe, however, that the amount of field trash accompanying the cane increased considerably on account of the abnormal amount of wet weather during the harvest season.

Mechanical improvements for the 1930 crop were, with the exception of one factory, largely in the boiling house, rather than in the milling plant. Honolulu factory removed their shredder, added another 3-roller mill and made other changes, which have resulted in improved milling work.

Table 8 lists the factories in the order of milling loss; Waimanalo and Hakalau are in first and second place for the third successive year. Ewa is now in 5th place and was 10th on the list in 1928. Olowalu occupies 6th place compared with 9th in 1929 and 14th in 1928. Pioneer is in 9th place, having risen from 17th place in 1929 and 25th in 1928. Hawaiian Sugar is now 10th, and was 21st two years ago. H. C. and S. Company is 11th, and was 15th in 1929 and 26th in 1928. Waimea was 30th in 1928, 23rd in 1929 and is now 18th. McBryde is 19th, compared with 32nd in 1929. Waianae has improved from 31st to 21st place in two years and Honolulu has improved from 34th to 28th place the past year. Factories that have dropped six places or more are Hamakua, Kekaha, Lihue and Paauhau.

Seven factories have bettered their positions four places or more and they are about equally divided between increases and decreases in grinding rate, but they all report an increased amount of imbibition water. Of the four factories that have poorer positions to the extent of 6 places or more, mentioned in the preceding paragraph, three report an increase and one a decrease in grinding rate and two have decreased imbibition while two have increased this figure. The influence of imbibition on milling loss was also discussed in the Synopsis last year.

TABLE NO. 8—MILLING RESULTS

Showing the rank of the factories on the basis of milling loss.

Rank	1929 Rank	Factory	Milling Loss	Extraction Ratio	Extraction	Imbibition	Tonnage Ratio	Tonnage Fiber Ratio*
1	1	Waimanalo.....	1.25	11.4	98.46	38.19	1.99	27.0
2	2	Hakalau.......	1.27	11.7	98.54	37.05	1.67	20.8
3	4	Honomu.......	1.66	15.2	98.20	35.90	1.52	18.0
4	3	Onomea........	1.71	15.2	98.07	34.45	2.14	27.2
5	6	Ewa..........	1.74	13.2	98.36	34.89	1.62	20.1
6	9	Olowalu.......	1.82	14.1	98.09	41.75	1.65	22.4
7	5	Hilo...........	1.90	17.0	97.69	35.00	1.96	26.6
8	8	Wailuku.......	1.96	16.2	98.05	39.79	1.21	14.6
9	17	Pioneer........	2.07	15.4	97.93	36.25	2.24	30.1
10	14	Haw. Sug.....	2.09	14.6	98.09	37.48	1.72	22.4
11	15	H. C. & S. Co...	2.10	14.7	98.23	44.23	1.65	19.9
12	11	Oahu..........	2.13	15.9	98.06	32.92	1.96	23.9
13	12	Kahuku........	2.15	19.3	97.71	30.68	1.73	20.6
14	13	Pepeekeo......	2.17	18.8	97.57	27.46	1.90	24.5
15	7	Paauhau.......	2.19	20.2	97.10	38.79	1.07	15.4
16	19	Hawi..........	2.22	19.4	97.39	23.88	2.07	27.8
17	18	Maui Agr......	2.34	16.0	97.78	41.29	1.72	23.8
18	23	Waimea........	2.37	18.0	97.75	29.95	1.62	20.2
19	32	McBryde.......	2.48	19.1	97.46	39.51	1.47	19.5
20	21	Koloa.........	2.48	20.8	97.29	37.61	1.43	18.6
21	28	Waianae.......	2.52	18.8	97.85	30.76	1.57	17.9
22	25	Hutchinson.....	2.65	22.1	97.12	27.85	1.94	25.3
23	20	Kohala........	2.66	24.8	96.96	33.86	1.58	19.3
24	10	Lihue..........	2.74	21.9	97.43	31.07	2.34	27.5
25	22	Haw. Agr......	2.83	24.6	97.23	18.36	2.01	22.7
26	16	Kekaha........	2.85	21.6	97.57	33.59	2.18	24.5
27	24	Laupahoehoe...	2.86	24.3	96.95	33.60	1.87	23.4
28	34	Honolulu......	3.18	23.3	97.27	34.13	1.56	18.3
29	26	Kilauea........	3.39	32.4	95.46	27.45	1.72	24.1
30	27	Makee.........	3.49	30.4	95.86	31.07	2.29	31.2
31	35	Kaiwiki.......	3.58	31.0	96.16	24.52	1.73	21.4
32	33	Waialua.......	3.62	27.3	96.45	34.34	3.01	39.1
33	30	Olaa...........	3.62	30.0	96.31	22.81	2.33	28.6
34	31	Waiakea.......	3.69	31.1	96.02	32.59	1.66	21.3
35	29	Hamakua......	3.71	32.1	96.01	26.18	1.42	17.7
36	36	Kaeleku.......	4.41	39.3	94.42	31.30	1.85	26.3
37	39	Union Mill.....	4.68	45.2	93.40	20.60	1.66	24.2
38	37	Honokaa.......	5.01	49.2	93.53	23.93	1.77	24.1
39	38	Niulii..........	5.84	61.9	90.85	25.09	1.94	28.7

* Tonnage ratio multiplied by per cent fiber in cane.

No records for extraction or milling loss have been broken this year by any factory. Factories reporting 98 extraction or over, number 10 against 9 last year, a previous maximum figure; H. C. and S. Co., and Olowalu report over 98 extraction this year, while Hilo has dropped below this figure.

Milling loss of less than 2.0 has been reported from 8 factories compared with 6 last year. The previous maximum was 8. The additional factories this year are Wailuku and Olowalu.

Boiling House Work

Clarification: The purity increase from mixed juice to syrup for non-Petree basis factories (Table 3) has increased to 1.44 from 1.35 last year. These figures are considerably below the maximum of 1.66 in 1927. Less lime, as available CaO, per ton of cane has been used this year, 1.30 lbs. against 1.38 lbs. last year, also less lime per cent non-sugars in mixed juice, the figures being 2.81 per cent for 1930 compared with 2.92 per cent for 1929. The average pH on hot limed juice has remained practically the same after making adjustments for the few factories reporting cold limed juice. A smaller proportion of factories have reported limed juice of less than the recommended minimum of 8.0 pH while two of the larger factories have reduced their reaction below 8 pH.

The larger purity difference between first expressed juice and mixed juice indicates the probability that more non-sugars than usual were extracted during milling, due to an increased amount of field trash. We have reason to believe from work done on last mill juices that a part of these non-sugars are quite readily precipitable in the clarification process. Such would favor the obtaining of a better purity increase from mixed juice to syrup.

The turbidity of clarified juice, 3.45 against 3.62 the previous year, is the lowest for the four years that these figures have been averaged.

Filtration of Settlings: Work at the filtration station has again improved. The loss per cent pol in cane (Table 3) is .44 against .52 last year. The present figure is the lowest for five years, and the loss is 15 per cent under last year, due chiefly to improved work at a number of the larger factories. The loss was lower at 17 factories, higher at 18 and without change at 2 factories. Oahu factory added one more Oliver vacuum filter to their equipment and their loss this year is less than half of that two years ago. Waialua discarded their old presses, installed new equipment and have reduced their cake loss to a low figure. Filtration equipment has been increased at 3 other factories. Cake pol (Table 3) was reduced from 2.27 to 1.82, or 20 per cent. There was a slight increase in weight of cake per cent cane, 2.96 against 2.87 last year, or 3 per cent.

Evaporation: Syrup density has increased to a record figure. The Brix is 64.34 compared with 63.65 last year and 63.04 in 1928. The calculated amount of evaporation per hour has increased 2.6 per cent this year. There were moderate increases of evaporator heating surface at 2 factories.

Commercial Sugar: The pol of commercial sugar has reached a new high figure of 97.66 though the increase was only .02. Twenty factories report increases against 17 reporting decreases. The Crockett refinery factories averaged 97.77

pol and those shipping to Western refinery 96.84. The spread in pol between the two groups was .93 this year and .87 last year.

Moisture and deterioration factor are both at new low figures. Moisture is .56 against .58 last year and the deterioration factor is .239 compared with .246 last year. The number of factories with a better deterioration factor has increased considerably, and factories reporting a factor above .25 number only 6 this year compared with 13 last year. Factories with just .25 were 6 this year and 7 last year.

Low Grade Sugar: The purity of low grade sugar is given in the first large table together with averages for six years. The purity increased slightly the first five years, but there has been a drop of .9 this year to the present figure of 75.7. Twenty-four factories reported lower purity this year, 14 higher purity and 1 no change.

Molasses: Final molasses purity is now at a new low record, 36.69, or .33 below the previous low figure of 1929. This is the fourth successive season that a lower figure has been obtained. The lower average this year is largely due to reductions in purity at the larger factories. Factories reporting lower purity than last year number 16 against 22 reporting higher purity. Additional crystallizer capacity was installed at one factory and three factories improved centrifugal equipment. Kahuku again has the lowest purity for the year, 32.84. The record low figure for the islands, 31.81, was established by the same factory in 1927.

The sucrose loss per cent pol in cane was slightly higher than last year, 7.45 against 7.40, in spite of the lower molasses purity, this being due to the lower juice and syrup purities.

In the following table the factories are listed in the order of molasses purity:

GRAVITY PURITY FINAL MOLASSES

32—33	33—34	34—35	35—36	36—37
Kahuku ...32.84	Ewa 33.91	Hutchinson.34.31	Haw. Sug..35.26	Oahu 36.09
	Koloa 33.91	Pepeekeo ...34.31	Honomu ..35.48	Onomea 36.20
	McBryde ..33.91	Pioneer 34.33		Hilo 36.22
		Hamakua ..34.46		Honolulu ...36.38
		Laup. 34.58		Waimanalo .36.54
		Hakalau ...34.74		Waianae ...36.62
				Maui Agr...36.66

37—38	38—39	39—40	Over 40
Lihue 37.00	Olowalu 38.61	Wailuku 39.39	Kilauea 40.22
H. C. & S. Co..37.15	Haw. Agr. 38.77	Kaeleku 39.43	Olaa 40.2
Makee 37.22	Kohala 38.80		Paauhau 40.82
Waialua 37.22	Hawi 38.81		Niulii 42.00
Waiakea 37.26			Kaiwiki 43.35
Kekaha 37.45			Union Mill ...43.80
Honokaa 37.76			

The number of factories in the above tabulation with molasses over 40 purity is one less than last year. In the 33 to 34 purity column there are 3 factories with identical figures, arranged alphabetically, and all tying for second place in the list. There are now 12 factories reporting molasses over 38 purity compared with 14 so reporting last year. None of the factories that still employ string proof boiling methods rather than crystallization in motion, report less than 38 purity and 5 out of the 6 factories listed in the last column follow the older practice.

TABLE NO. 9

COMPARISON OF ACTUAL AND THEORETICAL RECOVERIES

	Recovery % Calculated Recovery *				Recovery % Recovery Indicated by "Sugar Ratio" †	
Rank	Factory	Milling	Boiling House	Over All	Rank	Over All
1	Kahuku	97.71	105.20	103.14	1	102.44
2	Hakalau	98.54	102.31	101.12	3	100.92
3	Haw. Sug	98.09	102.46	100.74	2	101.19
4	Oahu	98.06	102.06	100.40	4	100.65
5	Honomu	98.20	101.95	100.40	5	100.60
6	Maui Agr	97.78	101.93	100.08	6	100.21
7	McBryde	97.46	102.39	100.07	12	99.53
8	Hutchinson	97.12	102.70	100.06	7	100.12
9	Waimanalo	98.46	101.18	99.90	14	99.04
10	Koloa	97.29	102.25	99.87	11	99.55
11	Ewa	98.36	100.81	99.44	9	100.02
12	H. C. & S. Co	98.23	100.85	99.30	8	100.04
13	Onomea	98.07	100.86	99.24	10	99.93
14	Lihue	97.43	101.29	99.08	15	98.92
15	Pepeekeo	97.57	101.20	98.93	13	99.08
16	Pioneer	97.93	100.68	98.91	16	98.68
17	Laupahoehoe	96.95	100.85	98.05	18	98.18
18	Wailuku	98.05	99.52	97.92	19	98.18
19	Waianae	97.85	99.81	97.92	21	97.85
20	Honolulu	97.27	100.20	97.70	17	98.53
21	Waialua	96.45	100.83	97.69	20	97.88
22	Hawi	97.39	99.45	97.27	26	96.85
23	Hamakua	96.01	100.57	97.16	27	96.01
24	Haw. Agr	97.23	99.62	97.13	22	97.55
25	Kekaha	97.57	99.11	97.11	23	97.26
26	Hilo	97.69	99.02	97.00	25	96.93
27	Olowalu	98.09	98.16	96.62	28	95.94
28	Kohala	96.96	99.14	96.42	24	97.12
29	Waiakea	96.02	99.72	96.08	29	94.95
30	Makee	95.86	99.24	95.67	31	94.55
31	Olaa	96.31	97.52	94.32	30	94.69
32	Paauhau	97.10	96.75	94.22	32	93.40
33	Honokaa	93.53	99.32	93.40	33	93.19
34	Waimea	97.75	95.05	93.18	35	92.99
35	Kaiwiki	96.16	96.10	92.71	34	93.17
36	Kilauea	95.46	95.21	91.59	36	89.87
37	Kaeleku	94.42	95.17	90.19	37	89.40
38	Niulii	90.85	97.71	89.19	39	87.84
39	Union Mill	93.40	94.88	88.96	38	88.90

* Factories are arranged in the order of the ratio of their recovery to that calculated on the basis of 100% extraction, 37.5 gravity purity molasses and no other losses.

† The basis of this calculation is 98.02 extraction, syrup purity one less than the apparent purity of the first expressed juice, gravity purity of molasses 33.33 and no other losses.

One factory, Oahu, made changes in crystallizer equipment that netted an increase in massecuite capacity of 40 per cent, and resulted in reducing molasses purity 3.17, thus fully justifying the expenditure. Other factories that made good reductions in molasses purity the past year were Waiakea, 2.29, and Hutchinson, 1.68. The former abandoned string proof boiling at the beginning of the 1929 crop and the latter a few years earlier. Hutchinson and Pepeekeo are now tied for fifth place in the above tabulation.

Undetermined Loss: The undetermined loss per 100 pol of cane has again been reduced and is .14, a record low figure. The average sucrose undetermined loss for all factories cannot be determined directly as 6 factories still do not report sucrose figures, but as pointed out under "Chemical Control," by applying the average difference for all factories reporting on both bases, the sucrose undetermined loss would be .98 per cent, or .13 below the corresponding figure for 1929 and a new low figure as calculated in this manner.

Recovery

The boiling house recovery has again increased for the third successive year. The increase this year was from 91.65 to 91.77 and is the highest figure in 21 years. In the earlier years of the sugar industry higher figures were obtained but these could readily be accounted for by the high juice purities then prevailing.

Total recovery is for the second year the highest figure recorded, it having increased .10 to 89.33. The better factory work this year should have increased total recovery about .34, but the poorer quality of cane as represented by lower purity of the first expressed juice and the larger drop from first expressed juice to mixed juice, have reduced the anticipated gain by about two-thirds. These two items reduced recovery in about equal proportion. The better factory work was divided about equally between better low grade work, better clarification and filtration results, and lower undetermined losses.

Quality ratio data compared with tons cane per ton of sugar indicate that due to poorer quality of cane a decrease in sugar yield of 2.96 per cent should have been secured this year while a decrease of 3.19 was realized. Correcting these figures for increase in fiber and the increase in sugar pol, they become 2.83 per cent and 3.31 less than the corresponding figures for last year.

Comparison of Actual and Calculated Recoveries

Table 9 is given in the same form as for the three previous years. The comparisons are based first as in Table 4, on 100 per cent mill extraction 37.5 gravity purity molasses, and no other losses; the second basis is: 98.02 extraction, syrup one less than apparent purity of first expressed juice, 33.3 gravity purity of molasses and no other losses. Large discrepancies in control data can influence these comparative recoveries; however, it is possible to exceed 100 per cent recovery on the theoretical on either basis without the figures being necessarily inconsistent.

These calculations are of value in pointing out the approximate quality of work in the various factories, but drawing too close distinctions is not justified, as a

satisfactory mathematical formula for judging the efficiency of factory operations has not yet been found.

The usual summary of losses is in Table 10.

The calculations in this Synopsis have been made by Mr. A. Brodie assisted by others in this Department.

TABLE NO. 10

SUMMARY OF LOSSES

FACTORY	Pounds Pol per Ton of Cane: Bagasse	Press Cake	Molasses	Undetermined	TOTAL	Pol per 100 Cane: Bagasse	Press Cake	Molasses	Undetermined	TOTAL	Pol per 100 Pol of Cane: Bagasse	Press Cake	Molasses	Undetermined	TOTAL	Syrup Purity	FACTORY
H. C. & S. Co.	5.0	1.4	16.4	—1.6	21.2	0.25	0.07	0.82	—0.08	1.06	1.77	0.52	5.70	—0.59	7.40	88.32	H. C. & S. Co.
Oahu	5.2	1.0	16.6	—2.0	20.8	0.26	0.05	0.83	—0.10	1.04	1.94	0.38	6.21	—0.73	7.80	86.80	Oahu
Ewa	4.4	1.0	17.0	2.4	24.8	0.22	0.05	0.85	0.12	1.24	1.64	0.38	6.45	0.95	9.42	85.64	Ewa
Waialua	9.4	0.4	19.2	0.1	29.1	0.47	0.02	0.96	0.00	1.45	3.55	0.17	7.28	0.02	11.02	85.90	Waialua
Maui Agr.	6.4	...	18.0	—3.6	20.8	0.32	....	0.90	—0.18	1.04	2.22	....	6.21	—1.24	7.19	87.67	Maui Agr.
Pioneer	5.6	0.8	19.4	1.0	26.8	0.28	0.04	0.97	0.05	1.34	2.07	0.29	7.19	0.42	9.97	85.62	Pioneer
Olaa	8.8	2.8	19.2	1.2	32.0	0.44	0.14	0.96	0.06	1.60	3.69	1.18	7.98	0.50	13.35	86.7	Olaa
Lihue	6.4	1.0	19.2	0.0	26.6	0.32	0.05	0.96	0.00	1.33	2.57	0.38	7.67	0.01	10.63	84.6	Lihue
Haw. Sug.	5.4	0.4	17.0	—2.2	20.6	0.27	0.02	0.85	—0.11	1.03	1.91	0.16	5.94	—0.78	7.23	86.98	Haw. Sug.
Honolulu	7.4	0.8	20.0	0.8	29.0	0.37	0.04	1.00	0.04	1.45	2.73	0.33	7.35	0.25	10.66	87.0	Honolulu
Kekaha	6.4	1.2	20.8	3.2	31.6	0.32	0.06	1.04	0.16	1.58	2.43	0.46	7.89	1.19	11.97	85.15	Kekaha
Onomea	4.4	0.4	16.6	0.1	21.5	0.22	0.02	0.83	0.00	1.07	1.93	0.18	7.41	0.03	9.55	85.71	Onomea
Hilo	5.2	0.6	17.6	3.0	26.4	0.26	0.03	0.88	0.15	1.32	2.31	0.24	7.90	1.38	11.83	84.92	Hilo
Haw. Agr.	6.4	0.8	19.2	0.0	26.4	0.32	0.04	0.96	0.00	1.32	2.77	0.30	8.35	0.01	11.43	85.86	Haw. Agr.
Honokaa	13.2	1.2	17.6	1.0	33.0	0.66	0.06	0.88	0.05	1.65	6.47	0.55	8.63	0.52	16.17	84.14	Honokaa
Makee	9.6	1.0	22.4	3.0	36.0	0.48	0.05	1.12	0.15	1.80	4.14	0.45	9.72	1.33	15.64	82.2	Makee
Wailuku	4.8	1.6	20.4	—0.6	26.2	0.24	0.08	1.02	—0.03	1.31	1.95	0.63	8.41	—0.23	10.76	85.7	Wailuku
Hakalau	3.2	0.4	15.6	—0.8	18.4	0.16	0.02	0.78	—0.04	0.92	1.46	0.18	7.22	—0.36	8.50	84.09	Hakalau
McBryde	6.6	1.2	18.2	—1.6	24.4	0.33	0.06	0.91	—0.08	1.22	2.54	0.46	7.02	—0.63	9.39	84.86	McBryde
Laupahoehoe	7.2	0.2	14.0	1.0	22.4	0.36	0.01	0.70	0.05	1.12	3.05	0.10	5.95	0.42	9.52	87.18	Laupahoehoe
Kahuku	5.2	0.6	18.0	—3.0	20.8	0.26	0.03	0.90	—0.15	1.04	2.29	0.32	8.05	—1.31	9.35	82.00	Kahuku
Hamakua	9.2	...	18.0	0.4	27.6	0.46	....	0.90	0.02	1.38	3.99	....	7.81	0.17	11.97	85.17	Hamakua
Pepeekeo	5.6	0.8	16.8	0.2	23.4	0.28	0.04	0.84	0.01	1.17	2.43	0.36	7.33	0.06	10.18	85.10	Pepeekeo
Paauhau	6.2	1.0	22.2	3.2	32.6	0.31	0.05	1.11	0.16	1.63	2.90	0.49	10.28	1.51	15.18	83.78	Paauhau
Waiakea	9.4	1.4	20.0	1.8	32.6	0.47	0.07	1.00	0.09	1.63	3.98	0.56	8.44	0.79	13.77	83.98	Waiakea
Koloa	6.4	1.6	17.2	—1.0	24.2	0.32	0.08	0.86	—0.05	1.21	2.71	0.69	7.27	—0.44	10.23	84.3	Koloa
Hutchinson	7.0	0.4	16.6	—0.8	23.2	0.35	0.02	0.83	—0.04	1.16	2.88	0.19	6.85	—0.31	9.61	84.44	Hutchinson
Hawi	6.0	1.2	22.0	2.2	31.4	0.30	0.06	1.10	0.11	1.57	2.61	0.51	9.64	0.94	13.70	82.73	Hawi
Honomu	4.0	0.4	17.2	—1.2	20.4	0.20	0.02	0.86	—0.06	1.02	1.80	0.16	7.78	—0.54	9.20	84.88	Honomu
Kaiwiki	8.8	1.2	22.4	3.2	35.6	0.44	0.06	1.12	0.16	1.78	3.84	0.56	9.70	1.36	15.46	85.19	Kaiwiki
Kohala	6.6	1.6	20.4	0.4	29.0	0.33	0.08	1.02	0.02	1.45	3.04	0.75	9.52	0.15	13.46	83.73	Kohala
Waimanalo	3.4	1.2	23.2	0.6	28.4	0.17	0.06	1.16	0.03	1.42	1.54	0.58	10.49	0.28	12.89	80.44	Waimanalo
Kilauea	9.4	3.4	28.6	3.0	44.4	0.47	0.17	1.43	0.15	2.22	4.54	1.59	13.65	1.49	21.27	80.1	Kilauea
Kaeleku	12.6	3.2	23.6	6.6	46.0	0.63	0.16	1.18	0.33	2.30	5.58	1.43	10.49	2.95	20.45	82.02	Kaeleku
Waianae	5.8	2.4	19.8	2.8	30.8	0.29	0.12	0.99	0.14	1.54	2.15	0.92	7.42	1.05	11.54	84.32	Waianae
Union Mill	13.6	2.4	23.2	2.0	41.2	0.68	0.12	1.16	0.10	2.06	6.60	1.20	11.22	1.02	20.04	83.89	Union Mill
Niulii	17.2	3.4	....	21.6	42.2	0.86	0.17	....	1.08	2.11	9.15	1.77	....	11.38	22.30	80.64	Niulii
Waimea	6.0	2.2	....	33.8	42.0	0.30	0.11	....	1.69	2.10	2.25	0.81	....	12.85	15.91	84.37	Waimea
Olowalu	5.0	1.2	23.4	4.4	34.0	0.25	0.06	1.17	0.22	1.70	1.91	0.47	9.08	1.70	13.16	83.65	Olowalu

Sugar Prices

96° Centrifugals for the Period Sept. 16 to Dec. 15, 1930.

Date	Per Pound	Per Ton	Remarks
Sept. 16, 1930	3.15¢	$63.00	Cubas.
" 22	3.145	62.90	Cubas, 3.15; Philippines, 3.14, 3.15.
" 23	3.135	62 70	Cubas, 3.13, 3.14.
" 25	3.13	62.60	Cubas.
" 26	3.10	62.00	Cubas.
" 29	3.045	60.90	Cubas.
Oct. 3	3.05	61.00	Cubas.
" 6	3.12	62.40	Porto Ricos.
" 7	3.13	62.60	Cubas, 3.14; Philippines, 3.12.
" 8	3.21	64.20	Cubas, 3.20, 3.22; Porto Ricos, 3.20.
" 9	3.26	65.20	Cubas.
" 10	3.2425	64.85	Cubas, 3.26, 3.25, 3.24, 3.22.
" 14	3.30	66.00	Cubas.
" 20	3.32	66.40	Philippines.
" 21	3.35	67 00	Cubas.
" 23	3.4375	68.75	Cubas, 3.40, 3.43, 3.45; Philippines, 3.45, 3.47.
" 24	3.42	68.40	Cubas, 3.45, 3.41, 3.40.
" 27	3.49	69.80	Cubas, 3.50; Porto Ricos, 3.48.
" 28	3.505	70.10	Cubas, 3.51; Philippines, 3.50.
" 29	3.39	67.80	Cubas.
" 30	3.38	67.60	Cubas.
" 31	3.42	68.40	Cubas.
Nov. 5	3.39	67.80	Cubas.
" 6	3 40	68.00	Cubas.
" 10	3.415	68.30	Cubas, 3.41, 3.42.
" 11	3.41	68.20	Cubas, 3.41; Porto Ricos, 3 40, 3.42.
" 13	3.45	69.00	Porto Ricos.
" 14	3.47	69.40	Cubas, 3.46; Philippines, 3.47; Porto Ricos, 3.48.
" 17	3.45	69.00	Cubas.
" 18	3.4033	68.06	Cubas, 3.42, 3.40, 3.39.
" 19	3.34	66.80	Cubas.
" 25	3.40	68.00	Cubas.
Dec. 2	3.41	68.20	Cubas, 3.40; Philippines, 3.42.
" 3	3.34	66.80	Philippines.
" 6	3.35	67.00	Cubas.
" 9	3.38	67.60	Cubas, 3.39, 3.37.
" 12	3.3533	67.06	Cubas, 3.35, 3.34; Philippines, 3.35; Porto Ricos, 3.37.
" 15	3.305	66.10	Cubas, 3.35, 3 26.

THE HAWAIIAN PLANTERS' RECORD

Volume XXXV APRIL, 1931 Number 2

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

We have learned with deep regret of the death of Dr. Frederick Muir in England on May 13, 1931. His work in the biological control of insect pests of sugar cane in Hawaii is a notable record of achievement in science and an outstanding influence in directing the economic entomology of the world toward the control of injurious insects by biologic means.

His work with the Experiment Station of the Hawaiian Sugar Planters' Association began in 1905. This was shortly after Dr. R. C. L. Perkins and Albert Koebele had made successful introductions of the egg-parasites of the sugar cane leafhopper.

Soon after that he undertook to find a natural enemy of the cane borer (*Rhabdocnemis obscura*) and after years of discouragement and illness contracted in his explorations, he discovered and successfully introduced to Hawaii the tachinid fly (*Ceromasia sphenophori*), largely reducing the heavy damage to cane crops caused by the borer since the beginning of the sugar industry in Hawaii.

In 1913 a new pest, an Anomala beetle (*Anomala orientalis*), had put in its appearance on an Oahu plantation and Dr. Muir, having traced its habitat to the Orient, proceeded to Japan in the search of its natural enemies. So much unsuccessful work had been done against similar root grubs in Porto Rico and Illinois, that little encouragement was found for the success of this venture.

The parasites which he found in Japan failed to become established in Hawaii, but his firm conviction in the biologic method of fighting insect pests did not waver. After continuing his work in Formosa he went to the Philippines, where the species of Anomala he was working to control did not in fact occur. But here he found a Scolia wasp (*Scolia manilae*) that was parasitic upon an allied species, and this on introduction to Hawaii became an effective enemy of *Anomala orientalis* and checked it to such an extent that it has not spread beyond a limited area.

Later, after observing the troublesome outbreaks of the sugar cane leafhopper that occurred despite the presence of the egg-parasites introduced fifteen years earlier, he held that since similar outbreaks did not occur in Australia and Fiji, other natural enemies of the leafhopper could be found. It was after a year of effort in Australia that his prediction proved to be correct. He found and intro-

duced to Hawaii an insect (*Cyrtorhinus mundulus*) that feeds upon the eggs of the leafhopper and this perfected the control of the pest that had taken such heavy toll from the sugar crops of the Hawaiian Islands.

While these professional achievements of Dr. Muir were along economic lines, his interest in the fundamental science of entomology was great. He believed that there was no dividing line between pure and applied science, that the two were inseparable. He was the author of many contributions to journals of entomology.

Dr. Muir was born in London, April 24, 1873. A large part of his earlier years were spent in Africa. In his death Hawaii loses a prominent benefactor, and one whose work stands as an inspiring example.

In This Issue:

Biological Control of the Coconut Moth in Fiji:

Dr. Muir's review of the book on the Coconut Moth in Fiji that was published last year appears with comments on various phases of the work involved in securing a parasite which was introduced and now controls the pest. Parallels are given between this work and some of our parasite introduction work in Hawaii.

Root Studies in Coimbatore:

In view of the increasing interest taken in the sugar cane root studies in these Islands, an account is given in this paper of the researches of the Coimbatore Station on this important subject.

Diseases, Malformations and Blemishes of Sugar Cane in Hawaii:

An outline presenting as near as possible a complete list of known diseases, malformations and blemishes affecting sugar cane in Hawaii is given. Following each disease the name of the causal agent appears.

Value of the Upper Joints of Cane:

An article supplementing a previous article of the same title based on experimental work of the writer, showing the approximate amounts of recoverable sugar in the upper joints of the cane stalk. An external reference point is given for locating joints of various qualities. Cost data are included for the items entering into the total cost of obtaining varying amounts of recoverable sugar.

Weather and the Quality of Juice at Ewa:

This paper deals with the specific relation of weather factors—such as sunshine, temperature, etc., to the average quality of juice of a typical irrigated plantation.

The significant fact is brought out that weather conditions exercise a very great influence on the average quality of juice of even an efficiently irrigated plantation. At Ewa, bright sunny days and cool nights are found to be the most important factors in improving the average quality of juice.

The Problem of Juice Quality:

With intensive fertilization and improved cultural practices, the yield of cane per acre has risen steadily during the last twenty years. The average quality of juice, on the other hand, has gone down just as steadily, so that today the average quality is only 60 per cent of what it used to be twenty years ago.

Added to this problem of gradual decline in the quality of juice, is the other problem of the great fluctuations in the juices from year to year.

Do these fluctuations and also the steady decline arise from any of our cultural practices or are they the work of some outside agencies—say weather conditions? For a proper understanding of this problem, we need to know all about the factors affecting juice quality.

In this paper is assembled information from various sources on the subject.

Cane Breeding in Coimbatore:

The good work of the Coimbatore cane breeding station is being increasingly recognized outside of India; we have recently imported several of its promising seedlings.

This paper gives a brief account of its researches and of what it has done for India from its start in 1913 to this day.

China as a Potential Sugar Market:

An interesting article in that it gives one an idea as to what conditions will have to be met before the per capita consumption of sugar by the Chinese is increased.

The Biological Control of the Coconut Moth *(Levuana iridescens* Beth.-Baker) in Fiji

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By F. Muir

The publication of *The Coconut Moth in Fiji*, by Messrs. J. D. Tothill, T. H. C. Taylor and R. W. Paine, is a notable event in the history of biological control of insect pests. It is of interest to entomologists in Hawaii for the reason that they have had personal contact with the entomologists of Fiji for a number of years, and there has been a number of return visits between them. Thus they have come to know one another's problems fairly well.

In 1905, when I first visited Fiji, this moth was confined to a part of the island of Viti Levu, although it had then been known in the island for nearly thirty years. It was then causing the authorities anxiety, and I was consulted by the Governor, and the Superintendent of Agriculture, as to possible remedies. I advised biological control measures, and suggested some of the islands in the Southwest Pacific as the probable home of the moth, and therefore the most likely place to find suitable parasites. I believe Albert Koebele had given similar advice some months earlier. The Governor, who was also a well-known zoologist, appeared interested in the idea, but it was twenty years before the advice was acted upon. It would be interesting to know the various reasons for the long delay. One reason, I feel quite sure, was the attitude of antagonism of most economic entomologists to biological control in 1905, and for some ten or fifteen years after. Except for a small group of entomologists in the United States, a small group in Hawaii and a few individuals in Europe, the whole of the economic entomological world was opposed to this principle of control. In 1910, a leading British economic entomologist told me that I was a fool for wasting my time; that I should do no good but a lot of harm. Time brought a change, and this entomologist lived to advocate biological control himself, although he never had a proper understanding of the subject. One of the factors bringing about this change was the economic success attained in the Hawaiian Islands.

It is possible that this coconut pest could have been controlled by artificial means, but the expense would have been greater than the industry could bear.

One of the things that has been brought out in the report is the gregariousness of *Levuana iridescens*, but I do not think enough use has been made of this to account for its slow rate of spread, and for some of its most marked characteristics. The larvae, upon hatching from the eggs, do not disperse, but feed together, and only the exhaustion of the food compels them to move to another leaf, even when full grown they do not seek solitude to pupate, like so many moth larvae, but congregate together to such an extent as to lead to the death of many pupae.

The adult has well-developed wings and, if endowed with a wanderlust, would soon have spread over Viti Levu, and even to other islands; but it has a strong nostalgia and will not seek new quarters, even to oviposit, but prefers leaves upon

which Levuana larvae are feeding. This leads to the enormous Levuana population in small areas, to the destruction of all its food plant and to the great economic loss; it also is accountable for the very slow spread of the insect. This psychology also played an important part in the control by the introduced Tachnid (*Ptychomyia remota*), as the percentage of parasitism as a rule can rise higher in dense than in sparse populations.

We have a somewhat parallel case in Hawaii in *Anomala orientalis*. This beetle spread very slowly, and increased to enormous numbers in the area of infestation. When the Anomala population became very dense it was often decimated by bacteria. The adult is a good flyer and it was a problem to account for its slow spread, as they were taken feeding on several plants. It was soon found that only males, and females that had already oviposited, frequented flowers: it was seldom that a gravid female was taken feeding. Mating takes place as soon as the female matures and she deposits her eggs in the vicinity. This was an important factor in its control by *Scolia manilae* as the parasite did not have to expend much energy in seeking its host. Thus we see a parallelism due to different causes.

Ptychomyia remota is not a native parasite on *Levuana iridescens*, but is attached to other, but allied, genera in Java and Malay States: *Scolia manilae* is also attached to allied species of Anomala in the Philippines, where *A. orientalis* is unknown. These two parasites have perfect control over their hosts in their new habitats. This indicates that it may be possible to use a foreign parasite to control a native insect under certain conditions.

It is fortunate, from a scientific viewpoint, that no other death factor of importance was established along with *Ptychomyia remota*, as it demonstrates once more what a single parasite can achieve under favorable conditions. Tachinids have a wonderful faculty of finding their hosts, and therefore their critical point of parasitism is often high. The Tachinid on our own sugar cane beetle borer finds its hosts, although they are embedded in the stalk of the sugar cane. The fecundity of *Ptychomyia remota* is very much lower than that of *Ceromasia sphenophori*, but then the former places its eggs upon its host, whereas the latter has to deposit them in the runs of the beetle borer larvae, and the Tachinid grubs have to find their host for themselves. The more direct the contact between the host and parasite the less need for high fecundity.

As *P. remota* has alternate hosts in Fiji it is likely to spread beyond the range of Levuana, and so be on the spot should Levuana spread. This is the case with *Scolia manilae*, which exists on Adoretus far beyond the present range of Anomala.

The account of Chalcid B and Chalcid A on Artona in Java (p. 240), and the injurious effects the latter has upon the former, recalls the limiting effect the hyperparasite has upon the Dryinidae in Hawaii.

In studying the Levuana work in Fiji, entomologists in Hawaii will find a number of phases of interest, on account of their similarities to those of their own work.

As the three authors spent some time in Hawaii, it is strange that the only reference to the work there is incorrect. They state that the beetle borer

(*Rhabdocnemis obscura*) threatened to destroy the sugar industry in Hawaii, and that its parasite (*Ceromasia sphenophori*) was introduced from Java. This Tachinid parasite is not known in Java, but in Amboina, Ceram and New Guinea, and was introduced from the last mentioned locality. The beetle borer has been in Hawaii for over sixty years and the sugar industry expanded in spite of it. It is true that it exacted a heavy toll during all these years, but it never threatened the life of the industry. It was the leafhopper (*Perkinsiella saccharicida*) that did this, and *Anomala orientalis* might have ruined some of the most fertile areas of the Islands if it had not been controlled.

The Coconut Moth in Fiji is published in a beautiful manner, the letter press and illustrations being exceedingly good. The Imperial Institute of Entomology must be given the credit for this.

The entomologists in Hawaii, through considerable experience, are well acquainted with the difficulties and dangers of all such work, and they congratulate all those who took part in finding and introducing and establishing *Ptychomyia remota* in Fiji.

Value of the Upper Joints of Cane

By W. L. McCleery

In a previous article (1) the writer pointed out the importance of adopting some systematic method for the proper topping of cane. Purities of the juices in the individual upper joints, starting from a reference point, were given together with values in terms of recoverable sugar. The data given in the preliminary report were from one series of determinations only. Shortly afterwards, ten other sets of experiments were run and the data herein presented are based on the entire eleven series of determinations.

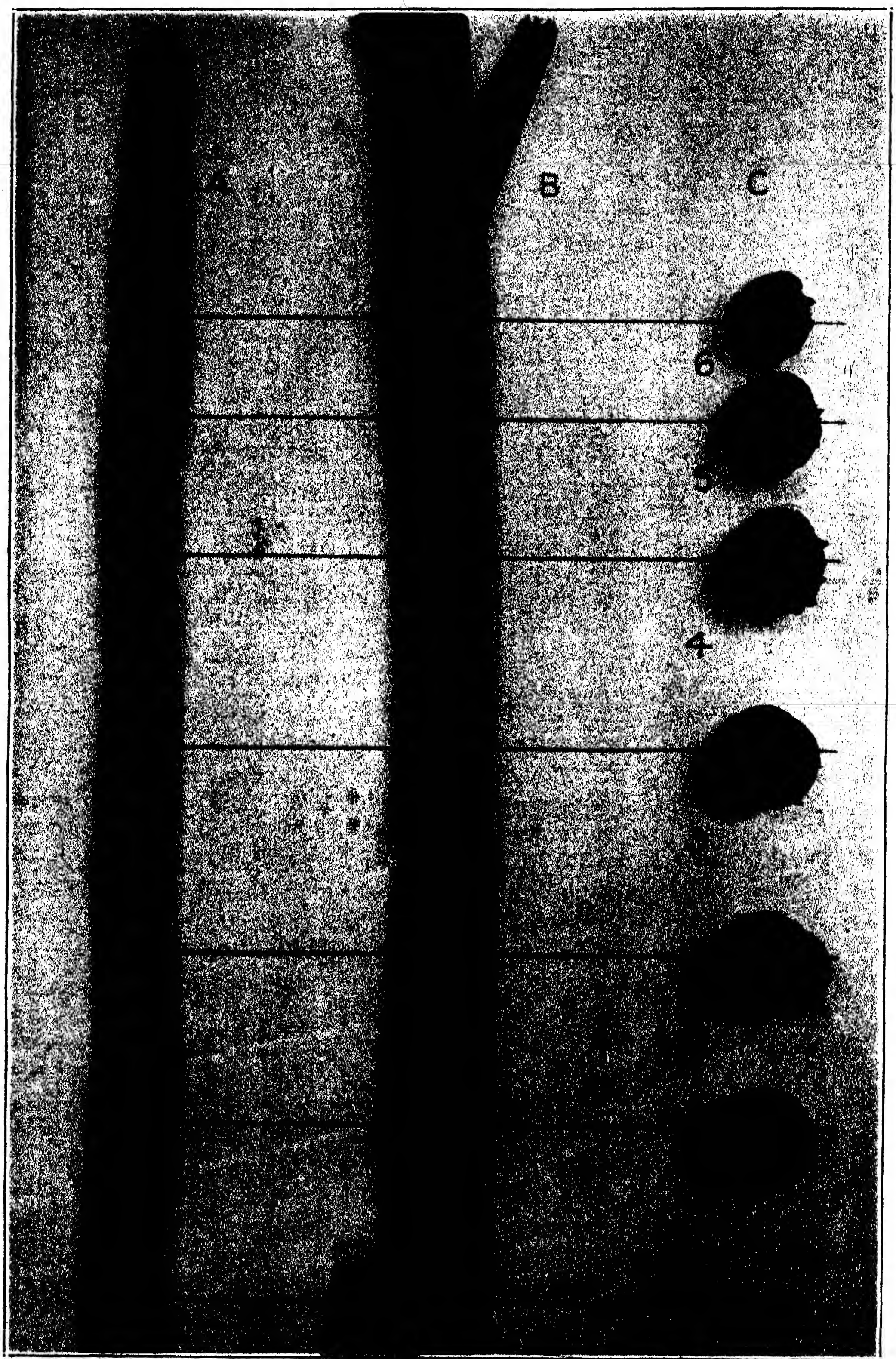
As pointed out in the first article, the greatest difficulty in an investigation of this kind is to determine a reference point that is strictly comparable and capable of duplication with all sticks of cane. Preliminary examination of cane stalks showed that the highest leaf that was tightly wrapped for the full length of its sheath, was attached to a node that had become slightly "weathered". This node having been somewhat exposed to light, had started to assume the color of the main stalk, and was called the highest weathered joint. This particular leaf sheath could be recognized on both burned and unburned cane as the tightly wrapped green leaves did not appear to be affected by the fire.

In the first experiment, designated Series No. 1 in the accompanying tabulations, 29 sticks of H 109 cane grown at the Experiment Station were used. Four sets of determinations were made and these were listed as joints 1, 2, 3 and 4. Joints 1 and 2 were below the center of the highest colored (weathered) joint, and Nos. 3 and 4 were above this point. The samples, including adhering leaves, to conform to actual practice, were chopped very fine and as much juice as possible was obtained under about 1200 pounds pressure per square inch. Analyses were made on both the juice and residual cake and all weights were recorded. Necessary data were also obtained on the main cane stalks.

Apparent purities in Series No. 1 ranged from 80.2 to 56.1 and the recoverable sugar, based on absolute juice gravity purity, from 233 pounds to 83 pounds per ton of joint. The first experiment also indicated that there would be recoverable sugar in the joints above No. 4, and in succeeding experiments the composition of joints 5, 6, and 7 was investigated.

The above results are in the tabulations following and are designated Series 1 to 5, inclusive. The samples, after the first series, were from fields being harvested on outside plantations. The reference point was the same as in the first series, joint No. 3 being cut at the center of the highest weathered joint.

To be able to investigate the composition of the topped material left in the field at the time of harvesting, it was found that a new reference point was needed. When cane is topped "high" the last weathered joint remains on the cane. On investigating cane tops from the bud downward, it is found that just below the bud there are several partly developed joints that are of almost jelly-like con-



A, Cane top with its leaves removed. B, Similar top with the leaves removed to the lowest tightly wrapped leaf. C, Sections made by cuts at the centers of the different internodes.

The most profitable point at which to top depends on the price of sugar and on the cost of cane delivered at the mill. With sugar at 3½ cents a pound top joints are worth saving if they contain 40 pounds of recoverable sugar per ton of joints when loading, transporting and manufacturing costs are included, 60 pounds if all harvesting costs are added, and, 100 pounds if cultivation costs are included.

sistency and which offer practically no resistance to pressure from the thumb nail. There is, however, a recognizable division between the soft joints and one that is firm enough, due to fibrous tissue, to resist moderate pressure. This point was designated as joint No. 1 in the remaining series of experiments beginning with Experiment 6. Investigations were also made to locate this point or a certain joint number in relation to the position of the highest tightly wrapped leaf sheath, so that an external reference point could be established. Information concerning this point is given later.

Experiments 6, 7 and 8 were each run on two series of samples marked A and B. The A series were on whole sticks and the B from tops collected in the same field as the A and as left by the harvesting gang. Joint No. 1 was the first (uppermost) hard joint, and No. 2 the next lower, etc. Subsequent observations showed that in general joint No. 1 corresponded with joint No. 7 in the earlier experiments, No. 2 with No. 6, etc. The average analyses of corresponding joints grouped in this way are so similar that an arithmetical average of the entire 11 experiments is given in the tables.

The results show, that in the lower joints investigated, somewhat over 200 pounds of sugar per ton of joint were recoverable and that the amount is less and less until an average of only 27 pounds per ton is recoverable in the uppermost hard joint. These values, when plotted, do not make a perfect curve, due to the limited number of tests, but the data are sufficiently complete to be of value in determining an approximate optimum point for topping.

J. D. Bond, in a report (2) on a series of five topping experiments at Ewa Plantation Company a few years ago, gives analytical data from the topped material when the cane is "topped low". "Topping low" he defines as "the removal of one seed piece of three eyes with the top". The upper limit of this seed piece is defined as "the removal of the top slightly below the growing point so as not to remove any stalk, and so that the cross section would show fibrovascular matter and no leaf spindle". The latter was defined as "topping high".

Data on the topped material on Bond's five experiments are given below:

Purity (Apparent)	Quality Ratio	Weight Per Cent of Cane as Topped High	Pounds Recoverable Sugar per Ton of Material
1. 41.48	195	4.66	10.2
2. 55.56	40	1.70	50.0
3. 43.72	116	2.82	17.2
4. 51.32	47	3.00	42.6
5. 50.22	52	4.37	38.4
Average	63	3.31	31.5

The sugar recoverable per ton of topped material was calculated from the quality ratio by the writer. The above data, in general, agree closely with those obtained by the writer for the higher cane joints investigated. Bond did not find as great a difference between individual tests, as did the writer, though his differences were large. This is readily accounted for as he was working with samples from several tons of material, while the writer's samples were from 25 to 30

sticks of cane only. The ripeness of the cane and purity of the juice in the main stalk also will cause fluctuations in the recoverable sugar in the upper joints.

The writer, in Experiments 6, 7 and 8, noted for each stalk the number of the joint opposite the center of the highest tightly wrapped leaf sheath. This was to ascertain if a certain joint could be located externally and serve as a guide in harvesting practice. In Experiment 6A the center of the leaf sheath was opposite joint No. 3 in most of the stalks, though there were a few No. 2 and No. 4 joints opposite the center. The same was true in Series 7A, though the uniformity was not quite as good and there were nearly as many second joints as third joints opposite the center. In Series 8A the average indicated that joint No. 2 was opposite the center of the leaf sheath. The above indicates that we appear to have an external reference point from which we can locate approximately any quality of cane material desired. The highest tightly wrapped leaf sheath is partly covered by the sheath of the next lower leaf, but the center or any other desired point can be quite readily located in topping practice.

TABLE A

Apparent Purities of Expressed Juice

	Joint No.						
Series No.	1	2	3	4	5	6	7
1	80 2	73.8	66.6	56.1	...	...	...
2	...	...	69.8	65.2	60.0	53.7	...
3	...	...	56.9	45.6	35.0	29.2	24.9
4	...	...	72.8	67.3	63.0	59 9	54.5
5	...	...	74.6	70.0	62.2	54.8	49.0
Averages	80.2	73.8	68.1	60.8	55.1	49.4	42.8

	Joint No.					
Series No.	6	5	4	3	2	1
6A	...	55.6	43 3	32.7	25.2	17.3
6B	...	65.4	51.6	41.0	28.9	22.4
7A	82.7	77.4	72.8	67.5	59.7	52.3
7B	83.4	74.8	67.5	64.1	56.3	56 5
8A	85.4	81.3	73.6	65.0	56.9	46.0
8B	...	...	...	63.6	...	50.3
Averages	83.8	70.9	61.8	55.7	47.3	40.8
General Averages	81.3	69.5	61.3	55.4	48.1	41.5

TABLE B

Gravity Purities of the Absolute Juice

	Joint No.						
Series No.	1	2	3	4	5	6	7
1	80.6	75.3	69.4	57.9	...	...	...
2	...	...	72.7	68.1	63 1	57.4	...
3	...	...	59.8	50.3	38.8	34.2	30.4
4	...	...	75.4	69.0	64.7	62.3	56.2
5	...	...	74.7	69.8	62.9	55.8	48.0
Averages	80 6	75.3	70.4	63.0	57.4	52.4	44.9

Series No.	Joint No. 6	5	4	3	2	1
6A	...	58.4	46.9	37.3	30.5	23.3
6B	...	67.6	54.7	44.7	33.9	27.9
7A	83.3	78.5	74.4	69.6	62.3	55.3
7B	83.9	76 2	69.6	66.4	59.1	59.3
8A	85.6	82.0	75.2	67.2	59.4	49.3
8B	...	...	...	65.9	59.6	53.4
Averages	84.3	72.5	64.2	58.5	50.8	44.8
General Averages	82.0	71 5	63.6	58.1	51.5	44.8

TABLE C

Weight of Upper Joints Per Cent of Cane Weight

Series No.	Joint No. 1	2	3	4	5	6	7
1	5.26	4.78	4.40	3.92	...	...	...
2	...	...	2.09	1.97	1.86	1.04	...
3	...	...	1.73	1.68	1.68	1.49	1.23
4	...	...	1.53	1.48	1 34	1.17	1.10
5	...	...	2.35	2.29	2.11	2.04	1.94

Series No.		Joint No. 6	5	4	3	2	1
6A		...	2.72	2.62	2.52	2.35	2.18
6B		...	2.49	2.28	1.16	0.60	0 31
7A		2.24	2.22	2.21	2.02	1.85	1.85
7B		1.18	1.07	1.00	0.85	0.61	0.41
8A		2.96	2 81	2.56	2.32	2.03	1.93
8B		...	...	...	2.00	1.07	0.62
Averages	5.26	2.79	2.34	2.20	1.79	1.43	1.29

TABLE D

Pounds Commercial Sugar Per Ton of Joint

Series No.	Joint No. 1	2	3	4	5	6	7
1	233	191	143	83	...	...	...
2	...	...	145	115	86	62	...
3	...	...	77	37	4	00	00
4	...	...	145	106	85	68	48
5	...	...	161	123	84	53	27

Series No.		Joint No. 6	5	4	3	2	1
6A		...	60	23	00	00	00
6B		...	115	50	17	00	00
7A		209	171	139	103	65	45
7B		229	163	116	85	54	56
8A		217	177	129	85	56	29
8B		...	...	...	97	65	41
Averages	233	212	136	92	65	42	27

TABLE E

Glucose Per Cent in Juice

Series No.	Joint No. 1	2	3	4	5	6	7
1	1.05	1.42	1.76	2.10	...	...	...
2	...	...	1.86	1.98	2 08	2.14	...
3	...	...	2.61	2.60	2.41	2.15	1.87
4	...	...	1.47	1.40	1.38	1.22	1.04
5	...	...	1.36	1.51	1.69	1.77	1.61
Averages	1 05	1.42	1.81	1.92	1.89	1.82	1.51

TABLE F

Ash Per Cent in Juice

Series No.	Joint No. 1	2	3	4	5	6	7
1	0.82	0.93	1.11	1.33	...	...	...
2	...	...	0.74	0.74	0.79	0.87	...
3	...	...	0.71	0.73	0.86	0.99	0.93
4	...	...	0.82	0.83	0.92	1 02	1.17
5	...	...	0.76	0.78	0.82	0.93	1.03
Averages	0.82	0.93	0.83	0.88	0.85	0.95	1.04

TABLE G

Glucose-Ash Ratio in Juice

Series No.	Joint No. 1	2	3	4	5	6	7
1	1 28	1.53	1.59	1.58	...	...	...
2	...	...	2.51	2.68	2.63	2.46	...
3	...	...	3.68	3.56	2.80	2.17	2.01
4	...	...	1.79	1.69	1.50	1.20	0.89
5	...	...	1.79	1.94	2.06	1 90	1.56
Averages	1.28	1.53	2.27	2.29	2.25	1.93	1.49

TABLE H

Sucrose-Ash Ratio in Juice

Series No.	Joint No. 1	2	3	4	5	6	7
1	19.29	14.58	9.92	6.16	...	...	...
2	....	....	14.55	12.25	9.70	7.51	...
3	....	....	10.22	6.79	3.91	2.77	2.55
4	....	....	12.80	10.33	7.88	6.06	4.38
5	....	....	15.22	12.36	9.01	6.11	4.26
Averages	19.29	14.58	12.54	9.58	7.63	5.61	3.73

Above has been shown the approximate amounts of recoverable sugar for various upper joints in the cane stalk, and also a method for locating externally where we may expect to find these amounts. The all important question remaining to be settled is the economic one. What does it cost to harvest, transport to the factory, and manufacture the recoverable sugar in these upper joints? After arriving at the costs, the market price of sugar will then determine whether there is a profit or a loss.

It is somewhat of a problem to determine the items which should be included in the total cost of this sugar. The cost of loading and hauling the cane material and also manufacturing and marketing the sugar will have to be included. It will take no more labor or materials to cultivate or cut the cane whether it is topped high or low. However, as our method of payment for these items is based on the weight of cane actually harvested, it appears that part or all of these charges of cultivating and cutting may need to be included.

Three cost tables are given below. The first table includes only loading, hauling, manufacturing and marketing charges. The second table, in addition to these charges, also includes cutting. The third table, in addition to the costs in the second table, includes cultivation. The latter item includes any or all of the following: Irrigation, hoeing, hilling up, cutting back, stripping, animal work, and clearing.

The cost figures are taken from the report of J. S. B. Pratt, Jr., (3) and are averages for four crops, 1925-1929, from twenty-two plantations. They are all on a per-ton-cane basis, with the exception of cost of marketing and containers, which has been assumed by the writer at $10 per ton of sugar. The separate average costs from Mr. Pratt's report follow, together with the three cost tables:

Cultivation, per ton cane	$ 1.26
Cutting, per ton cane	0.33
Loading, per ton cane	0.29
Hauling, per ton cane	0 47
Manufacturing, per ton cane	0.59
Marketing and containers, ton sugar	10.00

FIRST COST TABLE

Cost of Loading, Hauling, Manufacturing and Marketing Sugar from Upper Joints of Cane

	Pounds Recoverable Sugar per Ton Cane							
	20	40	60	80	100	120	140	160
Cost per Ton Cane.	$ 1.45	$ 1.55	$ 1.65	$ 1.75	$ 1.85	$ 1.95	$ 2.05	$ 2.15
Cost per Lb. Sugar	7.25¢	3.88¢	2.75¢	2.20¢	1.85¢	1.63¢	1.46¢	1.34¢
Cost per Ton Sugar	$145.00	$77.60	$55.00	$44.00	$37.00	$32.60	$29.20	$26.80

SECOND COST TABLE

Cost of Cutting, Loading, Hauling, Manufacturing and Marketing Sugar from Upper Joints of Cane

	Pounds Recoverable Sugar per Ton Cane							
	20	40	60	80	100	120	140	160
Cost per Ton Cane.	$ 1.78	$ 1.88	$ 1.98	$ 2.08	$ 2.18	$ 2.28	$ 2.38	$ 2.48
Cost per Lb. Sugar	8.9¢	4.7¢	3.3¢	2.6¢	2.2¢	1.9¢	1.7¢	1.55¢
Cost per Ton Sugar	$178 00	$94.00	$66.00	$52.00	$44.00	$38.00	$34.00	$31.00

THIRD COST TABLE

Cost of Cultivation, Harvesting,* Manufacturing and Marketing Sugar from Upper Joints of Cane

	Pounds Recoverable Sugar per Ton Cane							
	20	40	60	80	100	120	140	160
Cost per Ton Cane	$ 3.04	$ 3.14	$ 3.24	$ 3.34	$ 3.44	$ 3.54	$ 3.64	$ 3.74
Cost per Lb. Sugar	15.2¢	7.85¢	5.4¢	4.18¢	3.44¢	2.95¢	2.6¢	2.34¢
Cost per Ton Sugar	$304.00	$157.00	$108.00	$83.60	$63.80	$59.00	$52.00	$46.80

Similar cost tables can be worked out by individual plantations, using their own costs. These, together with the prevailing market price of sugar, will readily show the economic point for topping.

If, for example, the market price of sugar is about 3½ cents a pound, according to the first table, material containing slightly over 40 pounds of recoverable sugar per ton of joint is worth saving. On the basis of Table II, the line is at just under 60 pounds per ton, while with all the costs of cultivation included it is at about 100 pounds of sugar per ton.

On the basis of the average of the 11 experiments, Table D, 40 pounds of sugar per ton of cane is at about the second hard joint, 60 pounds at about the third hard joint, and 100 pounds at about the fourth joint.

These experiments for the most part were on ripe canes. Less matured or lower purity cane will have lower recovery figures for corresponding joint numbers.

Each plantation should work out figures for its own conditions. It can be assumed that the juice from topped material will have recoverable sugar if its purity is above the molasses purity of that particular factory. The amount will be shown by application of the s. j. m. formula. Experiments on clarification of last mill low purity juices show that a good increase of purity may be expected from upper joint material. These recoverable values were calculated on the gravity purity of the absolute juice and 37 gravity purity molasses. The above figures are, therefore, believed to be conservative.

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1. McCleery, W. L. 1922. Value of the upper joints of cane, Hawaiian Planters' Record, Vol. XXVI, p. 71.
2. Bond, J. D. 1928. The topping of cane at harvest. Hawaiian Planters' Record, Vol. XXXII, p. 19.
3. Pratt, J. S. B., Jr. 1929. Reducing production costs. Association of Hawaiian Sugar Technologists.

* Includes cutting, loading and hauling.

Cane Breeding in Coimbatore

By U. K. Das

(Note: The information contained in this paper has been obtained from the publications of the Cane Breeding Station at Coimbatore, from the Annual Reports of the Secretary, Sugar Bureau, Pusa, and from personal observations. A list of the relevant publications of the cane breeding station is appended, but in the body of this paper no attempt has been made to definitely cite any reference. Special thanks are due to the Government Sugar Cane Expert, through whose courtesy a number of illustrations appearing herein were secured.)

Introduction

The cane breeding station at Coimbatore was founded in 1912 by the Government of India, in response to a demand to help the native sugar industry in the face of extreme foreign competition. This station was first sanctioned as a temporary measure, but as a result of its excellent work, extending over a dozen of years, it was made permanent in 1925.

The main and immediate object of the new station was to breed improved varieties of cane for sub-tropical North India,* which grows over 80 per cent of India's total. Coimbatore, which is in the tropics and at a distance of about 2,000 miles from North India, was selected as the site of the station because, situated at the foot of the Nilgiri Hills at an elevation of about 1,000 feet, it enjoys a very mild climate and the canes around were known to flower freely and profusely, whereas in North India flowering of cane was almost unknown. In these respects Coimbatore is like Malang, where most of the breeding operations of Java are carried on at present.

The North Indian Cane Belt

The sugar belt in North India comprises the provinces of the Punjab, the United Provinces of Agra and Oudh, and Behar. The extreme growing conditions are met with in the Punjab, where the summers are unusually hot and dry and the winters very severe, with occasional frosts. The growing season is hardly eight months. From the Punjab as we move southeast toward the United Provinces and Behar, the climate gets milder and the growing season longer. Sugar cane has been cultivated in these parts from a very ancient time and the varieties that survive today are usually of the thin to medium type, with fair sucrose. The problem, then, before the new station was to breed cane varieties that would do well under the trying conditions of North India and yield more sugar than the trusted and tested varieties of the old.

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* **Since 1926, the scope of the station has been extended, and the breeding of thick canes for tropical India has been taken in hand.**

Raising of Seedlings—Breeding Material

The first efforts of the station appear to have been the collection of most of the important North Indian canes, and the collection from within India or by importation from abroad of a large number of thick tropical canes; for it was early recognized that the improved varieties for North India would most likely be crosses between the thick tropical and thin Indian canes. Thus as early as 1915, there were growing at the station 130 thick and 112 thin varieties of cane, besides the newly bred seedlings. As sugar cane breeding is still largely a method of "try and discard," a large assortment of breeding material is the *sine qua non* of rapid progress.

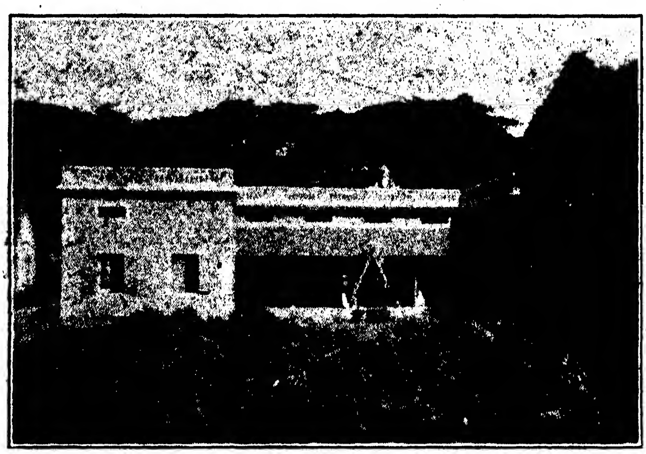


Fig. 1. A view of the cane breeding station, Coimbatore, India.

At the present time the breeding material at the station consists of several varieties of wild canes (*Sacch. spontaneum*), all the different groups of Indian canes, a large number of tropical varieties, and the selected Coimbatore canes.

Flowering

In Coimbatore, the flowering season extends from the first week in October to January. This season coincides with the east monsoon and as a rule there are some heavy showers and wind. Generally, the thick tropical varieties flower first, followed by the cross-bred seedlings and the thin Indian canes. Some of the spontaneums are in flower almost throughout the season. Not all varieties flower every year. Also, some that flower this year may not do so in the next.

Considerable difficulty was experienced in the beginning of this station in the matter of flowering, for though the local thick canes flowered freely, the imported North Indian canes refused to do so. Some of these canes were induced to flower by planting them on wet clay soil, and in 1915 as many as 36 thin varieties flowered at the station and most of them for the first time on record. Of the five groups of Indian canes, only two, namely, the Saretha and the Pansahi, have flowered freely so far.

The other three groups, namely, the Nargori, the Mungo and Sunnabile, are

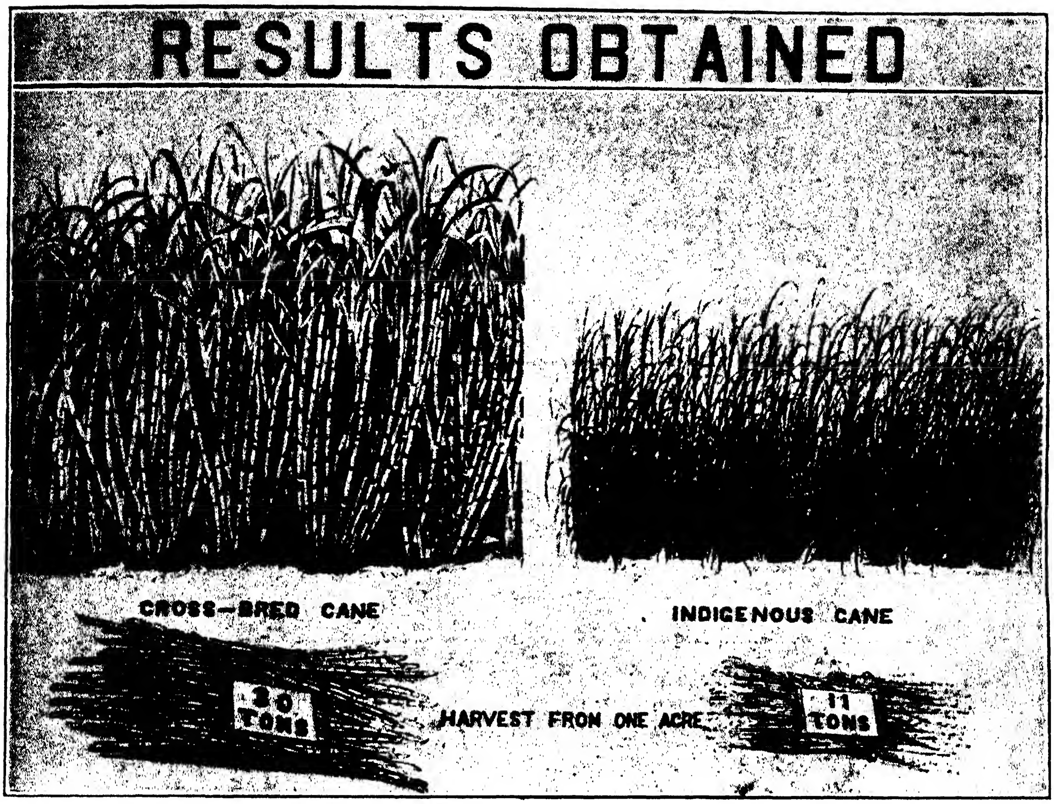


Fig. 2. The benefit to be derived from the creation of new varieties by scientific cane breeding is exemplified in this illustration. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

extremely erratic though producing occasional flowers. Even when a cane of any of these three varieties flowers, the essential organs are generally found to be undeveloped. From the breeding point of view, these three varieties are of great importance and success in inducing them to flower is likely to be of great consequence. Towards this end the station is, at present, working on several lines, such as (1) manurial treatments, (2) spraying the cane leaves with chemical solutions, (3) planting the recalcitrant varieties in different altitudes.

Time of Flowering

Next in importance to flowering is the time of flowering. As elsewhere, the cane breeding station has had to give up many valuable crosses simply because the two varieties would not flower at the same time. This is a problem that faces the cane breeder in every country and one that needs a speedy solution. The station has in the past achieved some measure of success by planting the varieties in different seasons, but the gain in time has not been considerable. A great deal of attention is being concentrated on this problem at present and the solution is being sought to two ways, (1) directly, that is, by hastening or retarding the time of flowering by such means as smoking of cane, cutting off a portion of daylight, application of certain chemical fertilizers, (2) indirectly, by storing cane pollen in

Fig. 3. A view of the smoking shed in the field. Here standing canes were smoked for weeks to promote early tasseling.

Fig. 4. Tile potting of selected stalks to induce root development at the nodes, so that these canes could later be cut off and isolated from the field when tassels emerged.

a viable condition for a certain length of time. As a result of experiments, it has been found possible to preserve cane pollen for 12 days in an atmosphere of CO_2.

Use as Male or Female

Usually the varieties that do not give pollen freely or do not give it at all are used as mothers and the prolific pollen givers as fathers. But at times, when it is intended to use a good pollen-giving variety as mother, the pollination is done early in the morning before the variety starts shedding its own pollen.

Pollen Fertility

The iodine test of pollen was used at first. It was, however, discovered that a simpler and more practical test would be the relative anthesis of a tassel because anthers fully dehisced invariably contained large numbers of well-developed pollen. None of these methods were perfecty satisfactory, as none gave any definite idea as to whether the pollens that had starch grains in them were actually viable at the time of cross-pollination. Artificial germination of pollen was first secured with some amount of success, by using the stigmas of "Datura fastuosa." In recent years considerable success has been attained in germinating pollen in an artificial culture of sugar solution.

Pistil Fertility

A great deal of useless labor can be saved if the fertility of a tassel can be determined before its use as a mother. The iodine reaction of the style was depended

upon for a long time, but more recent experiments have shown that while this iodine test applies satisfactorily to the thin Indian canes, it fails with the tropical canes, in the case of which the actual germination test is the only reliable one.

Controlling Dehiscence of Anthers

Sometimes it is necessary to effect a cross between two varieties located at a distance of days from each other. The difficulty of mating them has been solved by controlling the dehiscence of anthers of the male parent by placing it in a humid chamber and transporting it over the distance.

In this way it has been possible to control dehiscence for as many as 10 days. The same method has also been used to good advantage in crosses like *Sacch. spont.* x Karun (a tropical cane), a cross which is ordinarily rather difficult because of the free dehiscence and self-pollination of the spontaneum before the tropical cane starts to dehisce.

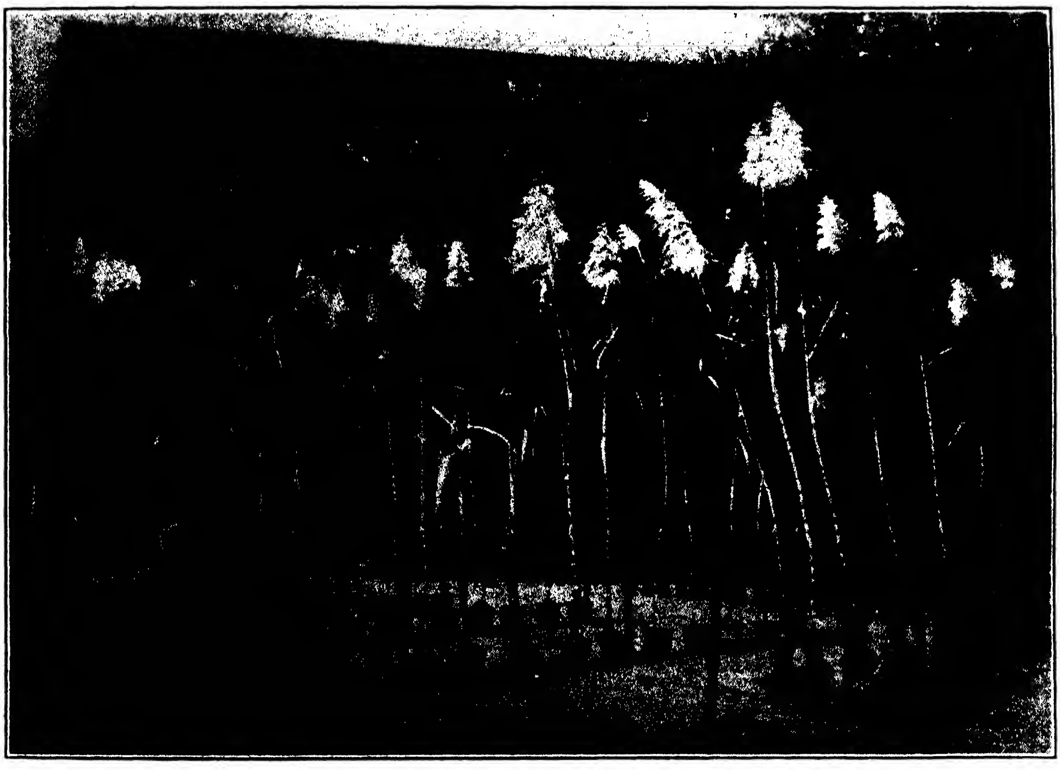


Fig. 5. A view in the breeding ground. Arrows isolated from the field after adventitious roots had been developed by layering the cane. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

Controlling Male Fertility

A great advance towards scientific cane breeding would be made if it were possible to render a tassel male sterile by artificial means. Towards this end, the Coimbatore station has been experimenting for some time past by growing cane tassels in various chemical solutions or under low temperature conditions. So far these experiments have not succeeded.

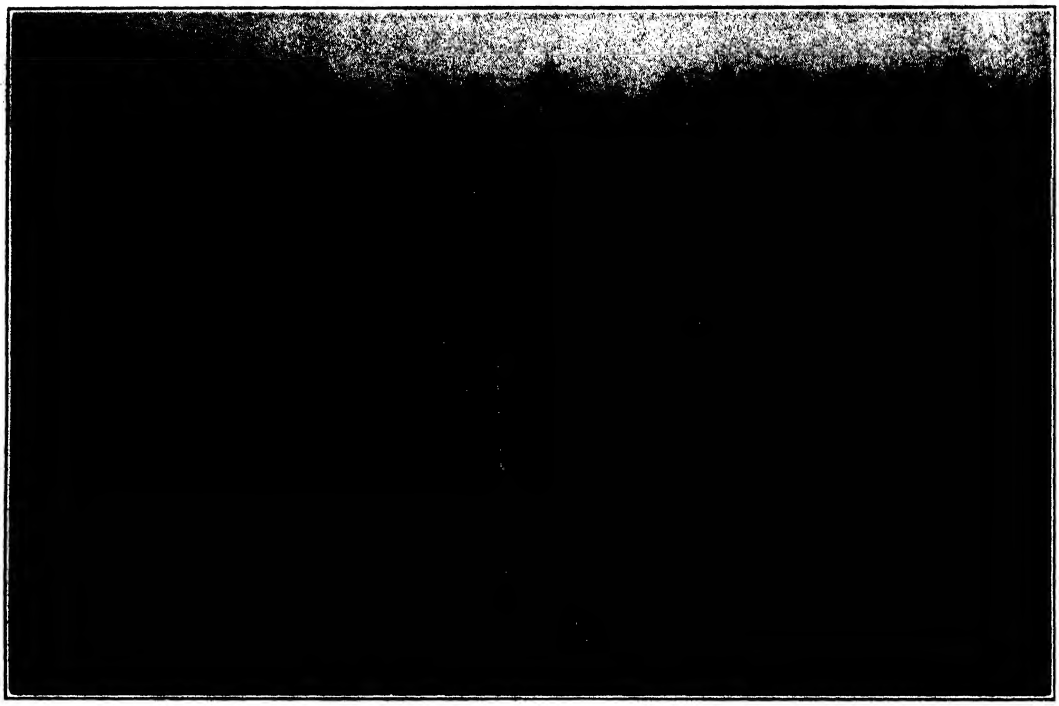


Fig. 6. First Ground Nursery. Seedlings are transplanted from the germinating pans directly to the fields. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

Crossing Technique

The first seedlings obtained at this station were from tassels collected in the field and designated as general crosses. In these crosses only the mother parent is known with any amount of certainty. Later on as needs developed for more exact knowledge of both the parents several methods were tried from time to time, the chief among which were (1) emasculation, (2) bagging together arrows grown in adjacent plots, (3) pollinating with male tassels brought from elsewhere and kept in water, (4) dusting the mother arrows with dehisced anthers or collected pollen, (5) artificial rooting method.

The emasculation method was given up after two years of trial, because it involved great practical difficulties owing to the delicate nature and minuteness of the florets.

The adjacent plot method, as well as the method of dusting the mother arrow with collected pollen, did not prove quite satisfactory owing to obvious reasons, and both the methods were slowly abandoned. The bagging of arrows was found to be harmful to germinating and seed setting; this practice was given up in 1916. Up to 1925, the method in general use was to keep the mother tassel growing in the field and pollinate it for a period of 4 to 5 days by placing over it a cut stalk of the pollinating parent, which was kept in a bottle of water. A fresh tassel was brought in every day.

The artificial rooting method was evolved in 1925. This method consists of inducing the flowering stalk to develop some secondary roots from root bands and then isolating the stalk from the field. As soon as the canes show indication of

tasseling by the sudden elongation of the stalks and simultaneous shortening of the leaves, a ball of soil is wrapped round one or two joints of the cane at a distance of several feet from the top of the arrow. The soil is kept moist by occasional watering. At the end of two or three weeks roots have developed sufficiently to be able to feed the part of the stalk above the treated joints. The stalks are then cut and taken to the hybridization sheds. Here they are placed in pots containing soil and the arrows continue developing without any setback. Cross pollination is made and the seed setting is in no way affected. This is undoubtedly a great improvement on the old method of breeding for it ensures the complete segregation of tassels from which results certainty as to the parentage of seedlings. This method has another sphere of great usefulness in making it comparatively easy to self cane varieties. The method suffers, however, from a slight disadvantage in large-scale operations in that it entails a great amount of labor and much preliminary work in the fields.

For large-scale operations, the method in general use consists of collecting spikelets of male flowers early in the morning before the anthers start dehiscing. These spikelets are then carried to the female tassel growing in the field and the pollen dusted on at the proper time. This method is very convenient and successful.

Collection of Seeds for Planting

As soon as the tassels get ripe, which takes about three to four weeks from the time of pollination and fuzz begins to blow, the tassels are cut and gathered in paper packets. The bags are kept in a cool and dry place for a few days, or at times dried for a day or two in the open, after which the fuzz is separated and planted in pans. Recent experiments have shown that the fuzz can be dried as effectively by putting it in an oven at 40° C. for a few hours.

The seeds are planted in earthen pots. The first pots used were about 12″ wide and 3″ deep; later on bigger pots, with a bottom 9″ wide and a depth of 6″ were substituted. At present the pans in use are cylindrical in shape, about 12″ wide and 6″ deep. The mixture in the pot consists of equal parts of rotten horse manure and fine river sand. Before using in the pots, the horse manure is freed of weed seeds by forcing them to grow and picking out the weeds. This method was originally borrowed from Java and has been in practice for all these years.

The fuzz is spread on the pan and watered with a rose from a height of about 3 feet, which beats the fuzz a little into the mixture and makes fine particles of sand adhere to the seeds. The pans are placed on the ground or on raised bamboo platforms, in the open air. These pans are left exposed outside even at night, except when rain comes, and they are covered.

The pans are watered three to four times a day so that the fluff is always moist. First germination takes place in 6 to 7 days; pans not showing any germination after two or three weeks are discarded.

The germinated pans are kept in full sunlight; and as the seedlings begin to produce roots which enable them to draw moisture from below the surface, the watering is reduced to once or twice a day. There is not much damping off in the

seed pans, although no chemicals are used to prevent the growth of algae and fungi.

The seedlings grow to a height of 2 to 3 inches in these pans before they are transplanted. At times when a pan is very much crowded, seedlings are picked off into a separate pan at an earlier stage. At the time of transplanting, the weak and very poorly growing seedlings are generally left behind. At times, as in 1923-24, as high as 30 per cent of seedlings are thus discarded.

First Ground Nursery

It was the custom in former years to transplant the young seedlings into individual pots. These pots were about a foot high and nine inches across, and contained a mixture of fine red earth, ordinary earth, cattle manure, and leaf mould in equal proportion. The pots were watered with a rose, or buried flush with the soil in trenches into which water was run.

In 1925, the pots were dispensed with, and now the seedlings are transplanted directly in the ground in what is called "The First Ground Nursery." For this purpose fields with a fair admixture of sand and soil are chosen. The soil is carefully prepared so as to obtain a fine surface tilth. Small raised beds are made of about 2′ wide, 4″ deep, and any convenient length, by taking soil from between the adjacent plots. This space in between is then used as a path to facilitate inspection of growing seedlings. Into these beds the young seedlings are transplanted from the pans, usually with a ball of soil around the roots. The plants are placed along the width of the row at a distance of 1″ from each other, the rows being 2½″ apart. The beds are watered immediately before and after transplanting. The plants are watered twice or more a day with a garden hose till they are well established, thereafter the water is supplied by irrigation channels dug on either side of the beds. When the plants are about 4″ high the rows are gently hilled up by drawing the soil from between them by means of a bamboo fork.

This technique of planting in the first ground nursery was slightly modified in 1928. The rows are now made 1′ apart and the plants put at a distance of 6″ to 8″ from each other. Furthermore, V-shaped sand veins are run along the length of the bed across the middle of the rows. Similar veins are run along the width of the bed midway between the rows. Irrigation channels are made on either side of the bed right from the beginning, and even at the earliest stages instead of watering with a can the water is run into the channels to be distributed to the plants along the sand veins. When the plants are a couple of inches high and well started, the lateral sand veins are opened and these, then, serve as small irrigation and drain ditches. These modifications have materially increased the vigor and health of the seedlings.

The great advantages of this method are: (1) saving in the cost of pots and the labor involved in using them, (2) more efficient and uniform distribution of water, (3) less chances of injuring the delicate little plants by applying water with a rose can, (4) better drainage, should that be necessary.

In this nursery the plants grow for two to three months. When they are about 1′ to 2′ high they are transplanted to the second ground nursery. In the past no

vigorous selection was made at this stage, only the very sickly looking plants being left behind. But last year this very preliminary selection eliminated almost 80,000 out of 100,000 seedlings raised.

The Second Ground Nursery

The land for the second ground nursery is prepared as carefully as the first. Plots ten feet wide and any convenient length are laid out, each plot having on one side an irrigation ditch and on another a drain. The plants are carefully transferred from the first ground nursery, usually with a ball of earth around them, and planted in rows at about 18″ from each other. Immediately after planting a copious irrigation is given. Henceforward, weekly irrigation is the rule. It becomes necessary sometimes to run a solution of tar emulsion into the fields together with irrigation water to prevent white ants, etc. Usually this transplanting into the second ground nursery is made in the months of May or June. Here they stay for eight to nine months, at the end of which time the seedlings are selected and analyzed and those that are retained are planted by sets into the final test plot.

Fig. 7. A small animal-driven mill for juice sampling.

Final Test Plot

Here the selected seedlings grow for a full year, at the end of which they are analyzed and rigorously selected, keeping in mind the locality for which they are intended. As outside rows are likely to grow better, due to their advantageous position, it is the custom to plant them with some standard cane.

The selected seedlings go to another field of a different soil type, and the following year to another, before they are finally sent out to outside stations for local variety trials. The purpose of planting them to different soil types is to get an idea of the possibility of a seedling under different conditions. For often it happens, as it did with Co. 281, that a seedling that grows poorly in one type of soil, thrives luxuriously in another. Thus it takes almost four years from the time the seedlings germinate to the time some of them are sent out as selected seedlings. In

the future it is proposed to shorten this period of testing by simultaneously planting the selected seedlings into three soil types.

Selection of Canes

In the earlier years selection was based primarily on sucrose. But it was soon found that without vigor and tonnage, mere sucrose was of no value. Also that in a group of seedlings from the same parents the ones that had high sucrose had invariably less vigor and growth. In other words, detailed study revealed the presence of an inverse relationship between vigor and richness of juice.

Nowadays canes are selected mostly on vigor and tonnage (actual weights are never taken, tonnage being judged by the eye alone), certain types such as the Punjab type and the Behar type signifying that for each locality certain characters must be given preference. Consideration of sucrose assumes a place of secondary importance, meaning thereby that while at times canes medium in sucrose may be selected for their vigor, sometimes canes very rich in sucrose are discarded because of lack of vigor. The cane that strikes the eye most is the cane that stands the best chance of being picked up. Also, to be selected, canes must have a straight habit, and, generally, early maturity. Recently importance is beginning to be placed on root development in selections, for it is felt that for each soil there is a definite type of root development that is likely to prove most satisfactory. Canes are also bred for disease resistance, but Coimbatore being more or less free of diseases, this point does not largely enter into consideration in selections made at the station. Only when the canes are sent out can this point be studied.

There is a great difference in the type of cane suitable for the different provinces, thus affording a greater choice.

Cane for the Punjab must be (1) resistant to frost, (2) early maturing, (3) resistant to drought or water-logging, (4) resistant to disease.

For Behar or U. P. the canes must be of medium type, able to benefit by irrigation or well distributed rainfall, (2) they may take a longer time to mature than those for the Punjab, (3) they must be disease resistant, especially to Mosaic.

The preliminary analysis is done when the cane is not fully ripe. In this analysis, especially when the canes are in the second ground nursery, the practice is to take only the portion of the cane up to the last dead leaf. For experiments have shown that this part of the cane gives a very good idea of the sucrose in the fully mature crop. The very first analysis may take only the Brix which is read in the field from the refractometer, the juice being obtained with a specially devised syringe. Sometimes small samples are run through a three-roller animal-driven mill, and Brix, sucrose, purity determined. Usually only those seedlings that come up to certain standards in the first analysis are analyzed the second time. The preliminary samples consist of two stalks only; larger samples are taken for full analysis. They are all random samples—a laborer goes through the field and selects the required number of average good stalks of the particular cane.

An idea of the rigorousness of selection can be gained from the statement of the year 1923-24; out of 130,000 seedlings raised, about 100,000 were planted in the first nursery, 80,000 in the second nursery, and only 10,000 in the final test plot.

And out of those 10,000 probably not more than 5 will receive the permanent number. Looking at it from another angle, roughly we may say, there have been raised up to date in Coimbatore 800,000 seedlings out of which only about 300, or 1 in 3,000, have received permanent numbers, and only about 10, or 1 in 80,000 has proved of commercial value.

Nomenclature—Distribution

Formerly the canes selected from the second ground nursery were given an "M" number, M standing for Madras, in which presidency the Coimbatore station is situated. Owing to confusion with M for Mauritius, the present practice is to name such seedlings "G," such as G1, G2, etc. The canes that are to be sent out to the provinces are given a "Co." number. No attempt is made to indicate as to what year they were raised.

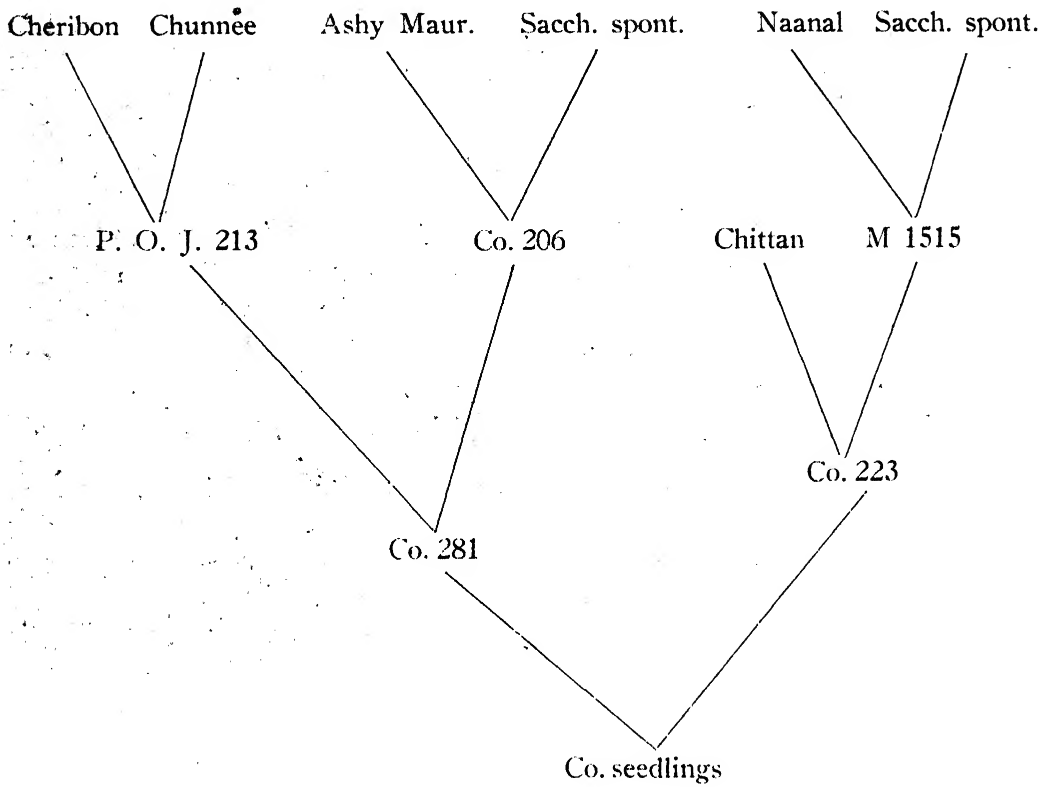
The cane station started work in 1913 and the first batch of seedlings was sent out to different places in India in 1918. In earlier years it was felt that a selected seedling should be tried several seasons to determine its consistency before being sent out. Experience soon proved that the variation in the seasons from year to year was naturally so great that the desired information as to consistency could not be gained even after several years of trial. Nowadays as soon as a seedling is noted promising and selected, it is sent out, and, as has been stated, it is proposed to further expedite this distribution.

Inheritance Studies

For some time past, the Coimbatore station has been devoting considerable attention to studies in inheritance, mainly for the purpose of obtaining information that will help the creation of new varieties. So far the studies have included (1) general field characters, (2) morphological characters of the leaf and cane, (3) root characters, (4) juice, (5) susceptibility to disease.

The inconsistency of data, probably due to the lack of sufficient material, makes it impossible to be definite on any point. But even the indications offer helpful suggestions, and it is claimed that such studies have already been of value in producing, by suitable mating, promising seedlings for sub-tropical India.

A TYPICAL GENEALOGICAL TREE OF THE MORE RECENT COIMBATORE SEEDLINGS



SOME IMPORTANT COIMBATORE CANES

(An excellent description of some of these canes appeared in *Agr. Jour. Ind.* Vol. 23, No. 1, 1928.)

Co. 205 (Vellai x Sacch. Spont.):

Thin cane, glaucous green color, grooveless, straight joints, hard rind.

Nowadays the standard cane in the Punjab. Hardy, vigorous, late maturing. "Resists frost, drought, water-logging and is specially suitable to unfavorable conditions of growth because of its remarkable root system. Susceptible to Mosaic and Pyrilla attack."

Co. 210 (P. O. J. 213 x Unknown), Field collected:

Brownish purple, thin to medium cane.

Fairly hardy, best ratooner of all the important Co. seedlings. Fairly resistant, more than 213, to drought, water-logging and frost. Early maturity. Grown extensively in Behar.

Co. 213 (P. O. J. 213 x Kansar):

Erect cane of medium thickness, brownish or pinkish yellow color.

Fig. 8. Co. 205—the poor man's cane. This remarkable cane will stand both drought and water-logging. Here is seen a field of Co. 205—5 months under water and giving about 18° Brix at harvest. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

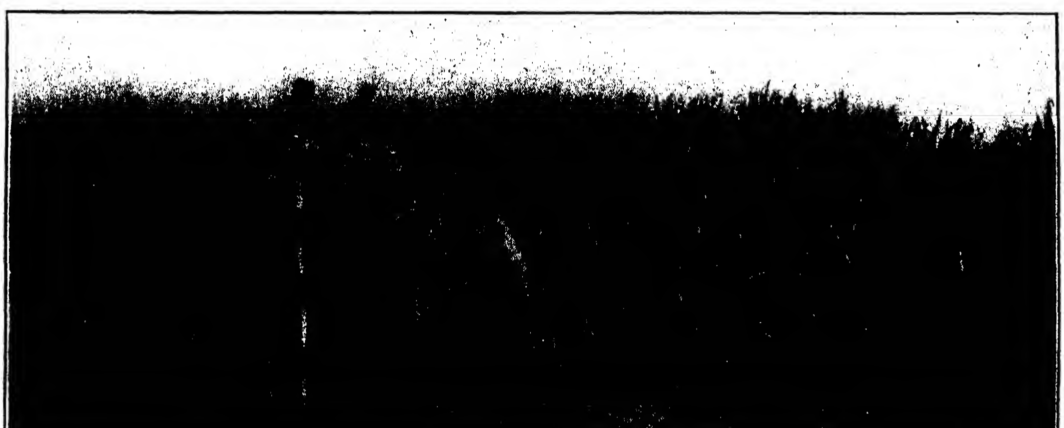


Fig. 9. A good field of Co. 213 in the provinces. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

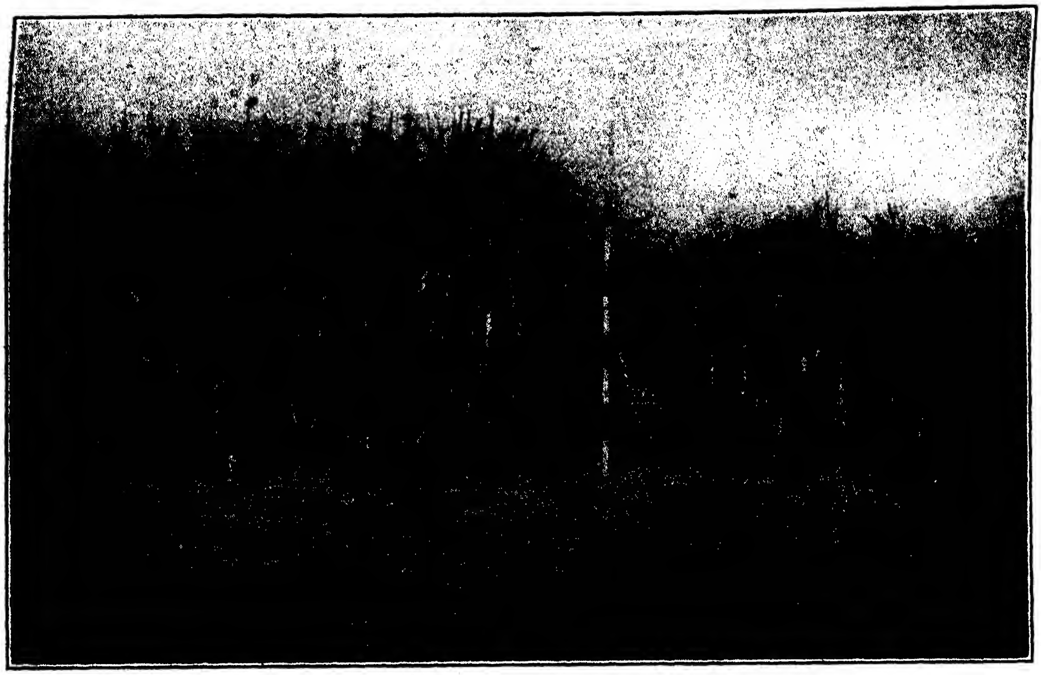


Fig. 10. Benefits of Breeding. Compare the stand of Co. 213 with that of the old standard cane Hemja (Co. 213 on the left, Hemja on the right). By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

The most widely cultivated Co. seedling, the standard cane in Behar and U. Provinces. Good habit, great vigor. Susceptible to Mosaic but not badly affected by it.

Co. 214 (Str. Maur. x M 4600) (M 4600 = Saretha x Spont.):

Thin cane, greenish yellow in color. Fair vigor, matures earlier than any other Co. cane, with a good quality of juice. Highly resistant to Mosaic. Preferred by mills as a cane for early season work.

Co. 281 (P. O. J. 213 x Co. 206) (Co. 206 = Ashy Maur. x Spont.):

A thin to medium cane, pinkish to brownish in color.

Good straight habit, vigorous grower. Deep root system, resistant to drought. Good juice. This cane is giving excellent results on the red exhausted soils in Cuba, but has no commercial importance in India.

Co. 285 (Green sport x Unknown) Field Cross:

Thin to medium cane, greenish yellow stalks. This cane is proving better than Co. 205 in the Punjab. It is more vigorous than Co. 205 and is less affected by diseases.

Co. 290 (Co. 221 x D 74):

Medium thick cane, brownish to pinkish yellow color, heavily waxed, good stooler, easy stripper.

This is, in my opinion, the best of all the Coimbatore seedlings. It is early maturing, has good juice, gives excellent yields and is commercially resistant to major cane diseases. It is, however, a cane that needs attention and good culture. I counted 196 well-formed stalks of this cane in a 40′ row in Coimbatore. The average stalk was about 1″ in diameter and 9′ to 10′ high, one year's growth. The neighboring row of D 74 had only 78 stalks, and less height. It is believed that this cane will soon replace Co. 213 in most parts of U. P. and Behar.

Fig. 11. Co. 290—5 months old. In the opinion of many, this is the best Coimbatore seedling. It has excellent vigor and good juice.

Lines of Work

The cane breeding station was started mainly for producing improved varieties of cane that would yield more and consequently make cane growing in India a profitable business. In the *Annals of Applied Biology*, 1915, Dr. Barber, the Government sugar cane expert, wrote:

> In all cases it will be our aim to cross good North Indian canes with good South Indian or exotics and in the case of the former the importance is recognized of choosing one parent which is largely grown and valued in the particular part of India to which it is intended to send the resulting seedlings for trial.

Unfortunately, however, this aim could not so easily be realized, for it was found that most of the North Indian canes, except the members of the Saretha group, refused to flower. Even when one or two of them did flower, they were found to be sterile. Attention was, therefore, turned to obtaining crosses between members of the Saretha group and the tropical canes, or the wild Saccharums and

the thin Indian or the tropical canes. The belief was more or less current at the time that the thin Indian canes might have originated from the wild Saccharums and, therefore, it was felt that a cross between a thick cane and a wild cane might give thin canes of the North Indian type. Thus in 1913, for the first time in history of cane breeding, large numbers of seedlings were obtained from a cross Vellai x S. Narenga. The seedlings, however, did not come up to expectations and neither could they be used in future crosses as they were infertile. But crosses between Vellai x S. Spont. proved more successful, and of this cross we have the new seedling Co. 205, which has become the standard cane of the Punjab. Attention was next drawn to the newer Java seedlings; these seedlings were known to combine the Indian Chunnee, the Java Cheribon and sometimes the wild blood. This line of work at once showed promise and it still continues to receive prominent attention. From this line of work has been evolved many of the famous Co. seedlings.

As has been the experience in every country, after the first big step in improvement has been made, further progress becomes exceedingly slow. It is easy to

Fig. 12. Contrary to usual experience, selfing is here seen to induce vigor. On the left Co. 205 and on the right a self of Co. 205 (M 58231), both of same age. Note the difference.

find a cane that is better than the old standard, but it is hard to find another cane that will beat this new cane by a fair margin. It may be either due to the fact that the new standard is high, or, as Professor Harrison declared in his presidential address to the planters of British Guiana:

In the earlier years working with natural varieties of sugar cane, several kinds of high promise are invariably obtained; in later years, when the mass of material for parental purposes has rapidly and enormously increased, the production of really good varieties appears to

be increasingly difficult. It looks as though the good results arose from the unravelling of the complex ancestry of the natural varieties, while similar results from the retangling of the new strains thus obtained are comparatively rare and very elusive. (*Agr. News*, Vol. XVII, No. 428, Sept., 1918.)

Very recently there has come a new line of research and one in which this sugar station stands alone in the world, namely, breeding improved canes by selfing. Both Co. 205 and Co. 214 are admirable canes, but both of them have some defects. Co. 205, for instance, gives impure juice and is late maturing; also it is subject to Mosaic.

Many attempts to repeat the cross proved disappointing. Co. 205 was, therefore, selfed. In 1927, 2,000 of such seedlings were raised, and of these one cane, Co. 229, was better than Co. 205 in respect to juice, but it lacked the vigor of Co. 205. Next year, 15,000 selfed seedlings were raised from Co. 229, and one of these (M 58231) appears to be the type wanted. An accompanying illustration (Fig. 12) shows Co. 205 and M 58231. The greater vigor of M 58231 will be noted. The same success appears to have been obtained by selfing Co. 214.

Another line of work being followed at present is to repeat the several promising crosses, raise a very large number of seedlings, thus to exploit the full possibilities of a particular cross. The breeding program at the station at present, therefore, consists of (1) raising a small number of seedlings from a few crosses, and to study type of seedlings obtained, (2) raising a very large number of seedlings from one or two very promising crosses, and to obtain from among the big lot canes of economic importance. Thus in 1928-1929, the bulk of the seedlings were from two crosses, namely: Co. 213 x Co. 214 and Co. 213 x Co. 281.

Attention is also being paid in recent times to creating seedlings which will have a certain type of root system that will naturally make them suitable to certain soil types. For deeper root system, the infusion of wild Saccharum blood has been found helpful.

For breeding disease resistant canes, either the wild Saccharum is used or canes that are known to be immune to the particular disease.

Very recently there have been attempts to raise canes for populating what are considered waste lands. The Indo-Gangetic plain has thousands of acres of land that will not grow anything but wild grasses. It is felt that if a seedling could be raised that would be as hardy and vigorous as the grasses but at the same time possess a certain amount of sucrose, say about 10 per cent, those lands might yet be made to produce something of economic value. There are now growing at the test plots of the station some thin seedlings which are considered quite promising, for this particular purpose.

Conclusion

It is estimated that the present area under the Coimbatore seedlings in subtropical India is well over 100,000 acres and that this represents an annual increased profit to the growers of nearly 100 lakhs of rupees (about $3,500,000) against an annual expense of about half a lakh on the station. These figures gain in significance when it is realized that things move slowly in a country like India. The Coimbatore station furnishes another excellent example of what can be

achieved in agriculture with the help of science. This station promises some day to become the savior of the dying sugar industry of India.

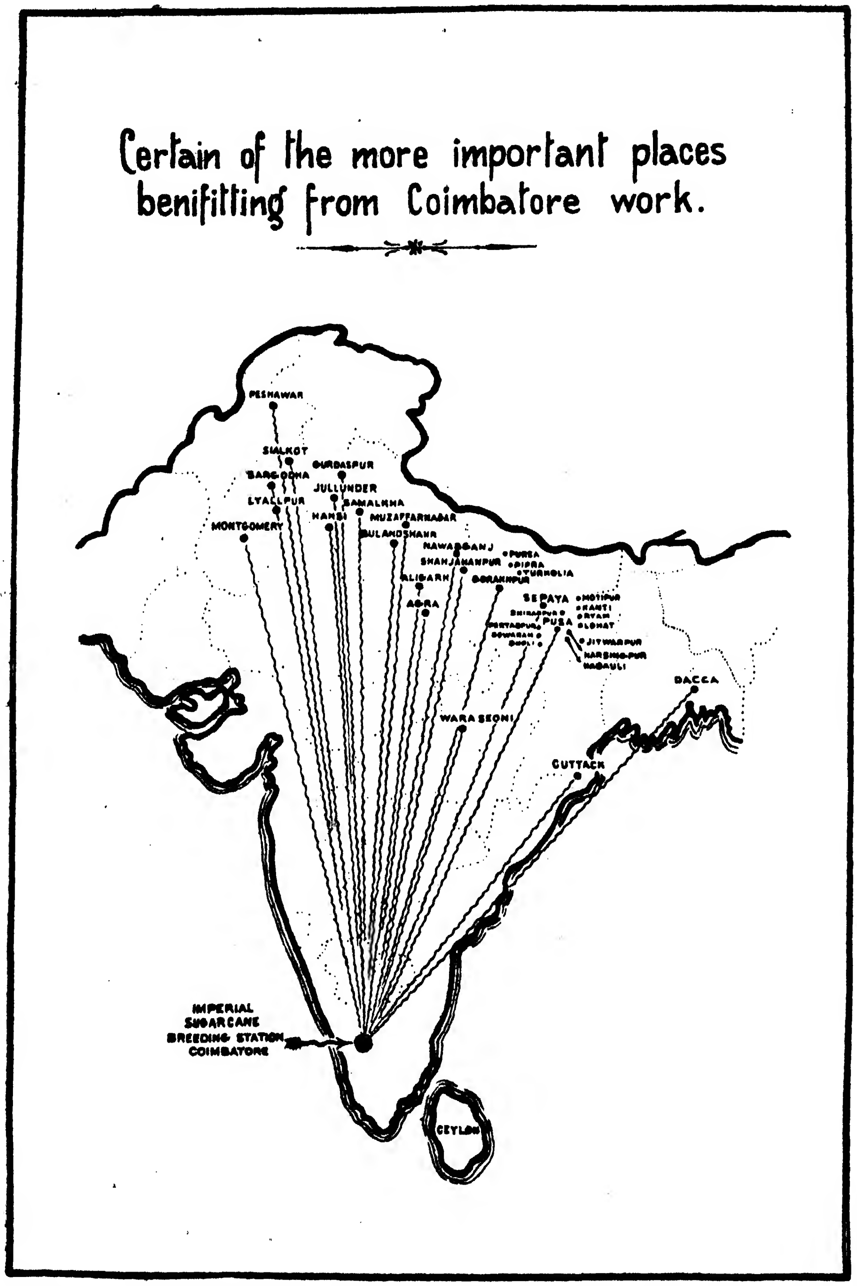


Fig. 13. The whole of India benefits from the work done in Coimbatore. The increased profit to the growers due to the introduction of new varieties runs into hundreds of thousands of dollars. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

LIST OF PUBLICATIONS FROM THE OFFICE OF THE GOVERNMENT SUGAR CANE EXPERT, COIMBATORE, AS OF DECEMBER, 1929

Serial Number	Title of Publication	Author	Reference
1.	Sugar and the sugar cane.	C. A. Barber	Agr. Jour. India, Vol. X, part 3, page 237. 1915.
2.	Some difficulties in the improvement of Indian sugar canes.	C. A. Barber	The Annals of Applied Biology, Vol. I, page 211. 1915.
3.	Studies in Indian Sugar canes, No. 1, Punjab Canes.	C. A. Barber	Mem. Dept. Agr. India, Bot. Ser. Vol. VII, page 1. 1915.
4.	Studies in Indian Sugar canes, No. 2, Sugar cane seedlings including some correlations between morphological characters and sucrose in juice.	C. A. Barber	Mem. Dept. Agri. India, Bot. Ser. Vol. VIII, No. 3, page 103. 1916.
5.	The classification of indigenous Indian Canes.	C. A. Barber	Agri. Jour. India, Vol. XI, part 4, page 371. 1916.
6.	A study of the arrowing (flowering) in the sugar cane with special reference to selfing and crossing operations.	T. S. Venkatraman	Agri. Jour. India, Spl. Ind. Sci. Cong., page 97. 1917.
7.	Study of the sucrose variations in successive cane joints as they attain maturity with special reference to the death of the leaves.	T. S. Venkatraman and K. Krishnamurti Row	Agri. Jour. India, Spe. Ind. Sci. Cong. No. 1917, page 117.
8.	Testing new cane seedlings in North India.	C. A. Barber	Agri. Jour. India, Vol. XIII, part 2, page 243. 1918.
9.	Studies in Indian Sugar Canes, No. 3, The Classification of Indian canes with special reference to the Saretha and Sunnabile groups.	C. A. Barber	Mem. Dept. Agr. India, Bot. Ser. Vol. IX, No. 4. 1917.
10.	Studies in Indian Sugar Canes, No. 4; Tillering or underground branching.	C. A. Barber	Mem. Dept. Agri. India, Bot. Ser. Vol. X, No. 2. 1918.
11.	The effect of salinity on the growth and composition of sugar cane varieties.	K. Krishnamurti Row	Agri. Jour. India, Spl. Ind. Sci. Cong. No. 1919, page 476.
12.	Studies in Indian sugar canes, No. 5; On testing the suitability of sugar cane varieties for different localities by a system of measurements. Periodicity in the growth of the sugar canes.	C. A. Barber	Mem. Dept. Agri. India, Bot. Ser. Vol. X, No. 3. 1919.

Serial Number	Title of Publication	Author	Reference
13.	Progress of the Sugar cane industry in India during the years 1916 and 1917.	C. A. Barber	Pusa Bulletin No. 83, 1919.
14.	A preliminary note on the behaviour in North India of the first batch of sugar cane seedlings distributed from the Sugar Cane Station, Coimbatore.	T. S. Venkatraman	Pusa Bulletin No. 94, 1920.
15.	A few hints on labelling in Experimental Stations.	T. S. Venkatraman	Agri. Jour. India, Vol. XV, part 1, page 45. 1920.
16.	Packing seed sugar canes for transport.	T. S. Venkatraman	Agri. Jour. India, Vol. XV, part II, page 174. 1920.
17.	Habit in Sugar canes.	U. Vittal Rao	Agri. Jour. India, Vol. XV, part IV, page 418. 1920.
18.	The care and treatment of new sugar cane importations.	T. S. Venkatraman and R. Thomas	Agri. Jour. India, Vol. XVI, part 1, page 24. 1921.
19.	A simple pollinating apparatus.	T. S. Venkatraman	Agri. Jour. India, Vol. XVI, part 2, page 203. 1921.
20.	Preservation of cut canes.	K. Krishnamurti Rao.	Mad. Agri. Dept. Year Book, 1920-21, page 89.
21.	Irrigation water for sugar cane cultivation.	K. Krishnamurti Rao.	Mad. Agr. Dept. Year Book, 1920-21, page 97.
22.	Germination and preservation of sugar cane pollen.	T. S. Venkatraman	Agri. Jour. India, Vol. XVII, part 2, page 127. 1922.
23.	Sugar cane root systems; Studies in development and anatomy.	T. S. Venkatraman and R. Thomas	Agri. Jour. India, Vol. XVII, part 4, page 381. 1922.
24.	A cheap and efficient method of propping sugar canes.	T. S. Venkatraman	Agri. Jour. India, Vol. XVII, part 4, page 416. 1922.
25.	Some suggestions to the grower of sugar cane.	T. S. Venkatraman	Mad. Agri. Dept. Villagers' Calendar, 1922-23, page 42.
26.	Sugar cane breeding in India.	T. S. Venkatraman	Imp. Bot. Conference, London, 1924, Rept. of Proceedings, pp. 57, 121.
27.	Simple contrivances for studying root development in agricultural crops.	T. S. Venkatraman and R. Thomas	Agri. Jour. India, Vol. XIX, part 5, page 509. 1924.

Serial Number	Title of Publication	Author	Reference
28.	Nursery Technique—India.	T. S. Venkatraman	Hawaiian Planters' Record, Vol. XXIX, No. 1, page 108. (Published abridged.) 1925.
29.	Sugar cane Breeding in India—Hybridization to testing.	T. S. Venkatraman	Agri. Jour. India, Vol. XX, part 3, page 173. 1925.
30.	Studies in sugar cane germination.	T. S. Venkatraman	Agri. Jour. India, Vol. XXI, part 2, page 101. 1926.
31.	Sugar cane Breeding Technique—Isolation of live arrows from undesired pollen through artificial rooting of canes.	T. S. Venkatraman and R. Thomas	Agri. Jour. India, Vol. XXI, part 3, page 203. 1926.
32.	Sugar cane Breeding—Indications of inheritance.	T. S. Venkatraman	Mem. Dept. Agri. India, Bot. Ser. Vol. XIV, No. 3, 1927, page 113.
33.	Breeding improved sugar canes for the Punjab.	T. S. Venkatraman	Agri. Jour. India, Vol. XXII, part 4, page 293. 1927.
34.	Sugar cane hybridization sheds.	T. S. Venkatraman and R. Thomas	Proc. of the 2nd Conference, Int. Soc. of Sugar Cane Tech., Havana, Cuba, 1927, page 124.
35.	Phyllotaxis and leaf obliqueness as separation characters in seedling canes.	N. L. Dutt	Agri. Jour. India, Vol. XXII, part 3, page 186. 1927.
36.	A method of studying the roots of sugar cane.	R. Thomas	Agri. Jour. India, Vol. XXII, part 2, page 138. 1927.
37.	An Improved Pitting Crowbar.	L. K. Narayanan	Agri. Jour. India, Vol. XXII, part 5, page 383. 1927.
38.	Coimbatore seedling canes. Co. 205, 210, 213, 214 and 223 described and illustrated.	T. S. Venkatraman and U. Vittal Rao	Agri. Jour. India, Vol. XXIII, part 1, page 28. 1928.
39.	A Leaf Adaptation conducive to Mosaic resistance in the sugar cane.	T. S. Venkatraman and R. Thomas	Agri. Jour. India, Vol. XXIII, part 1, page 56. 1928.
40.	The Indian Sugar Bowl and Agricultural Research in connection therewith.	T. S. Venkatraman	Pres. Address, Agri. Sec. Indian Sci. Congress, 1928. Agri. Jour. India, Vol. XXIII, part 3, page 166.

Serial Number	Title of Publication	Author	Reference
41.	Germination of sugar cane pollen in artificial culture media.	N. L. Dutt and G. Ganapathi Ayyar	Agri. Jour. India, Vol. XXIII, part 3, page 190. 1928.
42.	Factors influencing the growth and sugar contents of sugar cane.	K. Krishnamurti Rao	Agri. Jour. India, Vol. XXIV, part 2, page 91. 1929.
43.	Longevity of sugar cane pollen.	N. L. Dutt	Agri. Jour. India, Vol. XXIII, part 6, page 482. 1928.
44.	Studies of sugar cane roots at different stages of growth.	T. S. Venkatraman and R. Thomas	Mem. Dept. Agri. India, Bot. Ser. Vol. XVI, No. 5. 1929.
45.	What portion of the sugar cane to plant.	T. S. Venkatraman	Agri. Jour. India, Vol. XXIV, part 1, page 60. 1929.
46.	Certain features of sugar cane root systems and the importance of their study.	T. S. Venkatraman	Proceedings of the 1928 Convention of the Sugar Tech. Association (India)
47.	An apparatus for testing rind hardness in sugar canes.	Dr. A. N. Puri and T. S. Venkatraman	Proceedings of the 1928 Convention of the Sugar Tech. Association (India).
48.	Supply of sugar cane varieties from the Imperial Sugar cane Station, Coimbatore.	T. S. Venkatraman	Agri. Jour. India, Vol. XXIII, part 5, page 404. 1928.
49.	Problems before the sugar cane breeder (With special reference to Indian conditions).	T. S. Venkatraman	Proceedings of the 3rd Convention of the Int. Soc. Sugar Cane Technologists, Java. 1929.

APPENDIX

Current Investigations at Coimbatore

(Season 1930)

During this part of the year, i. e., from August to December, the investigations bear mainly on the problem of breeding.

Thin Cane Area

Arrowing—(I) The influence of the time of planting on arrowing—it is found possible to have a difference of two to three weeks in flowering by planting in different seasons. (II) The influence of nitrogenous and phosphatic fertilizers on

arrowing—phosphatic fertilizers hasten the time of flowering by a week or so. (III) Smoking to induce early arrowing—results inconclusive. (IV) Wrapping up and spraying of tassels in the field to prevent emergence of anthers—results negative.

Fertility, Receptivity of the Stigma—It is believed that the failure of the canes of the various Indian groups may be, in part, due to the dryness and consequent non-receptivity of the stigma. (I) Spraying the stigmas just before pollination with a 1 per cent solution of commercial sugar—last year's results with the thick canes rather encouraging—no data yet obtained from the thin canes.

Root Studies—Experiments to develop a method by which the functional regions of a root system can be studied. No success as yet.

Crosses made—Besides a few experimental crosses the following general crosses were made:

(I)—Co. 290 x Co. 281.
(II)—Co. 290 x Co. 214.
(III)—P. O. J. 2725 x Cholam (Andropogon Sorghum).

A very large number of Co. 214 selfed tassels were collected from the field. They germinated excellently. Also general crosses were gathered from the field, i. e., tassels were gathered from the field without reference to the pollinating parent. The cross between P. O. J. 2725 and Cholam is of more than passing interest. This is probably the first instance where a plant of another genus has been crossed with *Saccharum officinarum*. I am told that they were attempting this cross for the last two or three years and only this year it has succeeded. The appearance and other studies, I have been told, indicate definitely that the seedlings are real offsprings of P. O. J. 2725 and Cholam.

Thick Cane Area

Arrowing—(I) To control flowering by shortening the period of daylight or by prolonging it by artificial light—results nil so far. (II) To induce arrowing by enclosing the top in an atmosphere of ethylene chlorhydrin—results nil.

Fertility, Stigma Receptivity, etc.—(I) Inducing fertility by spraying the stigmas with 1 per cent sugar solution—last year's results encouraging—no data as yet on this year's work. It is claimed that by treating in this manner, seedlings were obtained from P. O. J. 2714.

Anthers, Pollen—(I) Controlling dehiscence of anthers or rendering pollen infertile by spraying with varying strengths of sodium chloride. (II) Experiments to preserve pollen in a viable condition over a long period.

Seeds, Seed Setting, etc.—(I) The effect of artificial rooting on seed setting (II) The effect on germination of soaking seed in orthophosphoric acid, or other chemicals. (III) The effect on germination of drying seeds in an oven of 40° C. or over—no data on any of these obtained as yet.

Selfing—The effect of keeping tassels in a closed room, on seed setting.

Crosses made—The following crosses were made:

(1) Vellai x Co. 213
(2) “ x P. O. J. 2878
(3) “ x B 3412
(4) “ x Co. 285
(5) “ x 247 B
(6) “ x P. O. J. 2696
(7) “ x D 74
(8) “ x Co. 281
(9) “ x M 58231
(10) “ x Q 813
(11) “ x Co. 290
(12) “ x Fiji B
(13) “ x Co. 243
(14) P. O. J. 2725 x Co. 243
(15) “ x B 3412
(16) “ x Co. 214
(17) “ x Fiji B
(18) “ x Co. 281
(19) “ x Co. 290
(20) “ x Q 813
(21) B 6308 x Q 813
(22) “ x Co. 281
(23) “ x Co. 290
(24) “ x D 74
(25) “ x M 58231
(26) “ x Fiji B
(27) Maur. 1237 x Co. 285
(28) “ x B 3412
(29) “ x Co. 243
(30) “ x D 74
(31) “ x M 58231
(32) “ x Q 813
(33) “ x Co. 281
(34) “ x Co. 290
(35) “ x Fiji B
(36) Co. 290 x 247 B
(37) “ x Q 813
(38) “ x S. W. 111
(39) “ x Fiji B
(40) “ x P 360
(41) Co. 213 x D 74
(42) “ x B 3412
(43) “ x P. O. J. 2878
(44) “ x S. W. 111
(45) “ x Q 813
(46) P. 384 (Co. 213 Self) x P. O. J. 2727.
(47) P. 384 x P. O. J. 2878
(48) “ x E. K. 28
(49) “ x D 74
(50) “ x S. W. 111
(51) “ x B 3412
(52) H 109 x Q 813
(53) Maur. 33 x Fiji B
(54) P. O. J. 2364 x Co. 281
(55) P. O. J. 2878 x B 3412
(56) “ x Co. 285
(57) “ x Co. 243
(58) S. W. 111 x M 58231
(59) Fiji B x B 3412
(60) Chittan x Co. 243
(61) “ x 247 B
(62) B. H. 10 (12) x Co. 290
(63) Kassoer x D 131
(64) “ x B 3412
(65) “ x Co. 290
(66) “ x Fiji B
(67) “ x B. H. (10) 12

Besides a few experimental crosses.

China as a Potential Market*

(*Abridged from "Commerce Reports"*)

China has long been regarded as a potential sugar consumer, but the purchasing power of the Chinaman is small and if the consumption of sugar is to increase the price must be kept low. In 1924 the *per capita* consumption of sugar was put at only 4 lbs., but at present is believed to range between 4½ and 5 lbs. This low figure is due to the poor standard of living of the masses. The poorer classes enjoy sweets, but consume sugar and candy sparingly. Agricultural products having a high sugar content, such as raw sugar cane and baked sweet potatoes, are sold on the street by the hawkers, as is hard candy of a decidedly poor quality. The Chinese use little coffee and still drink their tea unsweetened. Sugar candy or rock sugar is regarded as a luxury, selling as a sweetmeat in the interior. Soft white sugar is the most popular, being eaten with chopsticks.

Both cane and beet sugar are produced in China, the former having been cultivated for centuries, and records show that fair amounts of Chinese sugar were imported into New York during the 18th century. It has always been regarded as a luxury and has often constituted the tribute to the ruler from those provinces that cultivated it. Cane sugar is now produced principally in the provinces of Szechwan, Kwantung and Fukien. The estimated production in these provinces during 1927 was between 210.000 and 235.000 long tons. Beet sugar is produced principally in Manchuria and the provinces of Shansi and Hopei.

According to latest reports, there are ten refineries and six sugar factories in China, Hong Kong and Manchuria. The great bulk of the sugar made is produced in small mills employing crude processes. Three kinds of sugar are made, green (dark brown), brown (light brown) and white. The imported sugar is divided into five varieties—brown, white, refined, cube or loaf, and sugar or rock candy. Java, Hong Kong, Japan and Formosa being the principal suppliers. Brown sugar is used largely by the refineries for mixing with native sugar, but is also extensively employed by confectioners and bakers, and by native doctors. White sugar is classified according to color, the best grade being used by households of the better classes. Refined includes all sugar treated with bonechar, or of a color equalling or superior to No. 26 D. S. Sugar candy shows a wide latitude, including all kinds of sugar in large crystals, rock candy being the most popular.

Shanghai and Hankow are the most important sugar markets. Dealers from several Provinces have buying offices established there, as well as in Hong Kong, Tientsin and Swatow. The trade is believed to be shifting from British to Dutch control, as sugar from Java and Sumatra is selling in the local markets at prices less than the British product.

Only a few of the largest firms have an established marketing system. They

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* **Taken from *The International Sugar Journal*, February, 1931, Vol. XXXIII, pp. 61-63.**

have Chinese dealers throughout the interior who are bonded to the importing firm through the deposit of title deeds, bank guaranties, or other collateral. Sugar is shipped to the dealers on open account, and at the end of each month or other stated period the dealers remit to the firm the receipts, less selling commission from the sales. The ordinary importing firms do not have agents. They obtain orders for future delivery from the local sugar merchants and in turn place these orders abroad. Upon arrival of the sugar in the port, the firm notifies the local merchants, who, according to the terms stipulated in the buying contract, take delivery in 10 days, 1 or 2 months. The practice of taking delivery in 10 days is becoming quite general. The volume of "spot" business is insignificant. After taking delivery of shipment from the importing firm, the local merchant effects shipment to his customers throughout the region.

Brown sugar manufactured in China and Japan is packed in mat bags, reinforced with rattan or split bamboo strips of 133 lbs. (1 picul) to 200 lbs. (1½ piculs) net weight. Brown sugar from Java and the Philippine Islands is packed in jute bags of 220 lbs. net weight. White and refined sugar manufactured in China and Japan and white sugar from Java is packed the same as brown sugar. Refined sugar from Java and white sugar from Cuba is packed in double jute bags of 220 lbs. (100 kilos) net weight. Refined sugar from Hong Kong is packed in single jute bags of 133 lbs. or in cotton bags of 100 lbs. Cube and loaf sugar is packed in cartons of 1 lb. and 5 lbs. and shipped in cases of 50 lbs. net. Sugar candy from Java is packed in jute bags of 333 to 360 lbs. net weight, while that from the United States and Europe is in jute bags of 100 lbs. net, and that from Japan in wooden cases of 6-7 lbs. Upon arrival in China, the sugar candy is repacked in cartons and tins, ranging in size from an ounce or so to 5 or 10 lbs. net. This article is in high favor as a gift, and for this reason the cartons and tins are usually attractive.

Imports of sugar into China during the last five years, for which statistics are available, according to statistics taken from "Foreign Trade of China," issued by the Inspector-General of Customs at Shanghai, were as follows:

Year	Long Tons
1928	818,091
1927	599,715
1926	696,600
1925	687,275
1924	530,360

Competition in the Chinese sugar market is very keen. If one is to compete successfully, it will have to be on a price basis, meeting quality requirements on a parity with competing sugars now established in the local trade. To be introduced successfully, it may even be necessary to sell slightly below current prices, until a foothold is obtained.

[J. N. P. W.]

Root Studies at Coimbatore

By U. K. Das

Systematic studies of sugar cane roots have begun only in recent times. Such studies give invaluable information not only to the scientist who wants to know all about the plant he is dealing with but also to the actual grower who can profit by them to improve his cultural practices. Lee and his associates in Hawaii and Venkatraman and Thomas at Coimbatore have done considerable amount of pioneer work. The work in Hawaii was confined to the thick canes only. The Coimbatore work, on the other hand, embraced different species of wild Saccharums, as well as different groups of the cultivated form of sugar cane. The work in Hawaii was more quantitative seeking to get exact information as to the amount of roots that are obtained at different depths of the soil, etc. The Coimbatore work, by the very nature of circumstances, lent itself more to interesting qualitative and comparative studies.

Summary of Coimbatore Work

Attention was first drawn to the interesting differences among the varieties, when, in the earlier years of the Coimbatore Station, a large number of stools were dissected to obtain information on tillering, etc. Real work appears to have started somewhere in 1919 and 1920. The first paper (1) by the joint authors appeared in 1922. It was shown in that paper that the different varieties had characteristically different root systems, that in the same variety the nature and the quantity of roots varied according to the type of soil, that the type of soil even modified the cell tissues of the roots and that a characteristic root system could be imparted to seedlings by suitable selection of parents.

In the second paper (2) the authors set forth the results of their detailed studies on the influence of the different types of soils on root systems, on the functional regions of the sugar cane roots, on the activity of root hairs, etc.

In the third paper (3) the authors have given detailed information on the development, nature and function of primary roots and adventitious roots ("Sett" roots and "Shoot" roots respectively—as the authors have called them). This paper also describes "certain interesting adaptations in sugar cane roots, such as aerotropic curvatures and arrangements for ensuring an efficient rooting."

Technique

In studying root systems of plants growing actively in the soil, a reliable technique is of the utmost importance. In fact it is the absence of an efficient technique that impedes progress along this line. In Coimbatore, the following methods have been tried:

(1) Dig pits on both sides of the cane stool at a certain distance from the

center—remove the soil slowly and carefully so as not to disturb the course of the roots or break them.

(2) Dig pits on both sides, insert iron rods across, wash the soil through these rods leaving the roots exposed and held between the rods.

(3) Lay strips of wire netting in the soil in the bottom of the row, plant cane as usual. At the desired time, remove the soil by washing. This method is open to great criticism, as the soil thus artificially prepared may not give the exact conditions found normally in the field.

(4) Make a column by placing several earthen rings one upon another. The rings have sides of one foot. Put wire netting in between the rings, fill the column with soil. taking care to simulate the texture in the field. Plant cane as usual, on the top of the column. At any time, rings can be removed to study the development of roots. This method, for obvious reason, is rather unreliable.

(5) Water culture—the cultures being made in earthen pots which are placed in the field itself. This method is useful only to a limited extent.

(6) In studying "Sett" versus "Shoot" roots, the authors have used the following method: Plant a piece of cane several internodes long, vertically in the soil. Allow only the topmost bud to sprout. Direct the shoot roots into the soil held in a paper tube. The tube is made of thick paper and paraffined outside and inside. It is claimed that by placing a particular type of soil in the tube, the development of roots in that soil can easily be studied.

The method generally employed at present is the first one. Pits are dug 3 to 4 feet away from the center of the row. Trained women laborers then get into the pit and with the help of a thin iron rod, pick the soil carefully so as to leave the roots intact in their place. Sometimes the roots are held in place by inserting a thin bamboo stick in the ground. Should a root break, in spite of all the care, the broken portions are at once joined together by a ball of clay. After the dissection has been completed, the roots can be seen in the pit more or less in their natural position; as the accompanying illustrations will show. Dissection of one side of a stool of cane may take one to two days. One man and two women are employed for the purpose. The pits may measure 5 feet by 3 feet or more and as many feet in depth.

After the system, thus exposed, has been studied, the soil is put back.

This method gives an excellent idea of the root system at any particular time; but it is doubtful if the same stool can be dug again to give reliable information as to the progress of the roots since the last excavation. This method is extremely laborious and would be quite expensive in Hawaii.

Attempts are being made to devise a method by which the actively growing roots can be studied *in situ*. No method used so far can give an exact idea as to the feeding ground of the root tips and root hairs.

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(3) Venkatraman, T. S., and Thomas, R. 1929. Studies of sugar cane roots at different stages of growth. Memoirs Dept. Agri. in India, Bot. Series, Vol. XVI, pp. 145-157.

Fig. 1. Exposed root system of a wild cane (Sacch. Spont.).

Fig. 2. Women laborers in the pit carefully removing soil from around the roots.

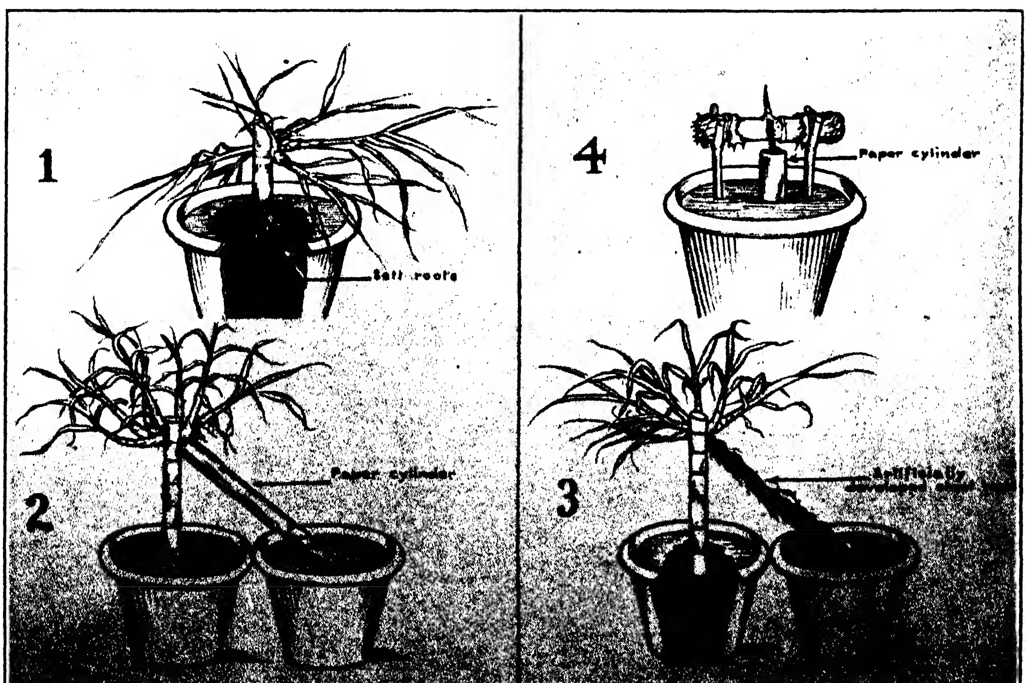

Fig. 3. Method of studying root development—the adventitious roots are being led into tubs containing different kinds of soil (No. 3). By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

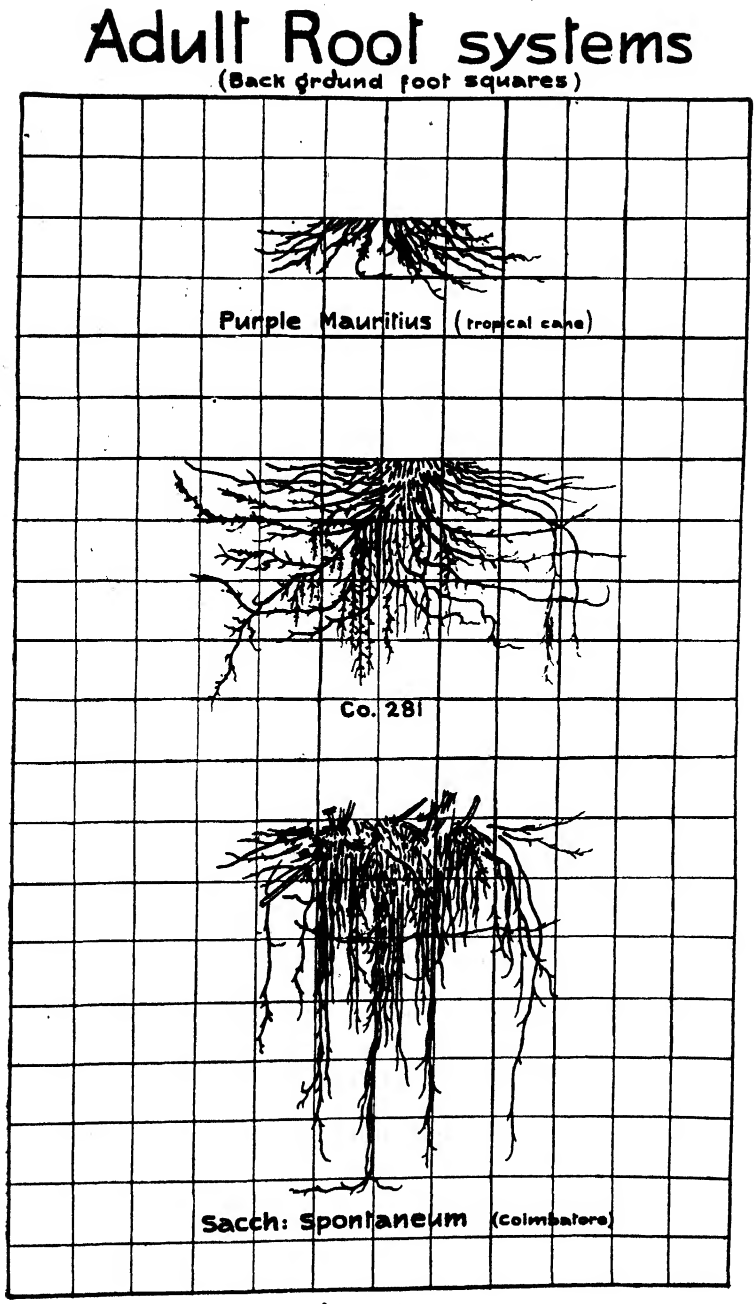

Fig. 4. Note the differences in the mode of root growth. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

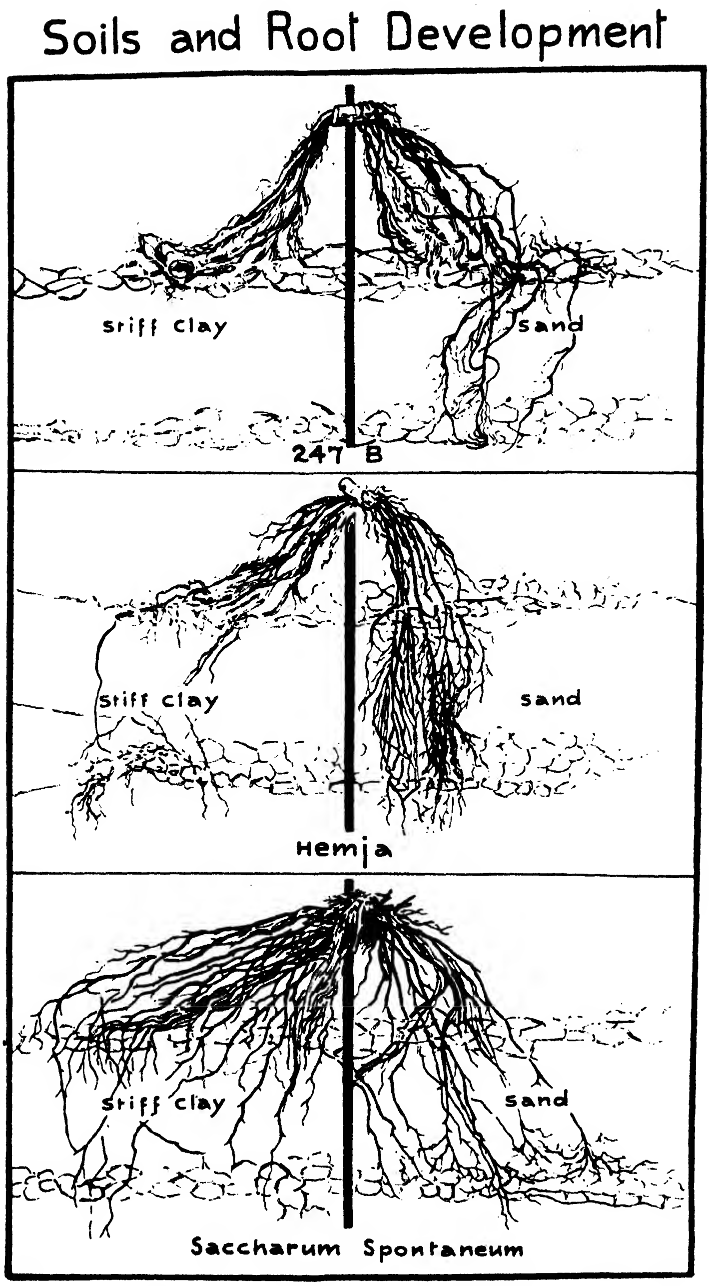

Fig. 5. 247 B and Hemja show much better root growth in a sandy (loam) soil but the wild cane Sacch. Spont. is equally at home in both the stiff clay and the sandy loam. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

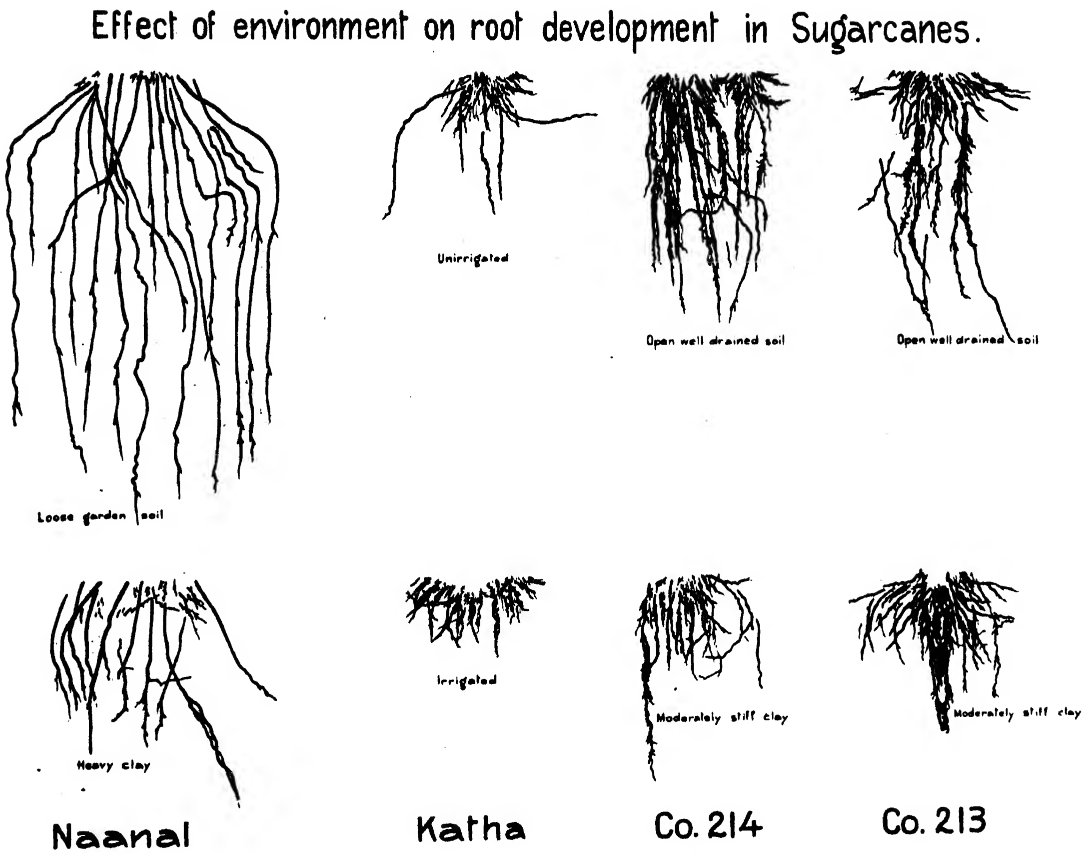

Fig. 6. This picture brings out not only the varietal differences but also the differences in root growth due to varying environments. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

Diseases, Malformations and Blemishes of Sugar Cane in Hawaii

By J. P. Martin

New or heretofore unrecorded diseases are observed from time to time accompanying the propagation of new cane varieties, the modification of agricultural practices, as well as variations that may occur in environmental or climatic conditions. It is possible that these diseases have been present for a long period of time in an inconspicuous or latent form and their symptoms are only recognized with the culturing of new varieties that prove highly susceptible, or, with a change of conditions, favorable to their development. It is well established that some varieties are highly resistant to specific diseases and yet may act as carriers without manifesting any definite symptoms of a diseased condition. The existence of certain diseases is more easily detected when susceptible canes are cultivated in contact with the highly resistant ones. For this reason observations made on mixed groups of seedlings of different parentage offer the best chances for detecting new troubles or abnormalities.

A disease is manifested by a deviation from the normal function or structure and is usually recognized by structural changes, depressed growth, development of abnormalities, the presence of various types of chlorosis, the occurrence of definite spots, stripes, blotches, or markings, or the interruption of physiological activities of the plant. A disease may affect a portion of or the entire plant and may cause a premature death of that portion of the plant affected.

Diseases affecting sugar cane plants may be divided into three groups, namely (1) non-parasitic, due to poor physical qualities or conditions of the soil, nutritional disturbances, environmental conditions, etc.; (2) parasitic, due to specific organisms such as fungi or bacteria living at the expense of the cane plant, and (3) virus diseases, due to ultra microscopic entities of unknown nature which are so small that they will pass through the pores of a Berkefeld or Chamberland filter and still be capable of producing a disease. Insects play an important role in this group of diseases since they frequently act as carriers of the virus and incidentally inoculate healthy plants during their search for food.

Articles pertaining to the major cane diseases have appeared in the *Hawaiian Planters' Record* and occasional mention has been made of the minor troubles. The object of this article is to present, as nearly as possible, a complete list of all known diseases, malformations and blemishes affecting sugar cane in Hawaii. It will be necessary to extend the present list as new diseases are observed.

In presenting this outline the cane plant, for convenience of discussion, has been divided into its component parts, namely: leaves, leaf sheaths, stalks, roots and tassels; another grouping has also been used which includes the entire plant. Certain diseases, for example, are recognized by the presence of definite symptoms appearing on particular parts of the plant; thus the maladies affecting or occurring

on the leaves have been listed separately. A further division has been made according to whether the symptoms of the diseases affecting the leaves assume the form of spots, blotches, streaks, stripes, a wilting or rolling of the leaves, a rotting of the spindle, a malformation of the cane top, irregular bands, various types of chlorosis or burns. The diseases affecting the other parts of the plant are handled in a similar manner.

Following each disease the name of the causal agent appears. Insect injury resembles a diseased condition under certain circumstances and for this reason is included in the following outline:

I. AFFECTING THE LEAVES	CAUSAL AGENT
A. SPOTS OR BLOTCHES ON LEAVES	
Eye spot	*Helminthosporium sacchari* Butler (fungus)
Brown stripe	*Helminthosporium stenospilum* Drechsler (fungus)
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Ring spot	*Leptosphaeria sacchari* van Breda (fungus)
Sooty mold	*Capnodium* sp. (fungus)
Red discoloration of midrib (Red rot disease)	*Colletotrichum falcatum* Went (fungus)
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Mosaic	A filterable virus
Banded chlorosis	Low temperatures
Purple discoloration	High elevations, low temperatures, lightning injury, and inherited characteristics
Pale whitish blotches near or adjoining leaf sheath	Inherited characteristic
Midrib blotch	Undetermined
Mechanical abrasion	Mechanical friction or wind whipping
Lightning injury	Lightning
Leaf stipple	Undetermined
Leaf freckle	Undetermined
Reddish blotches due to leaf mites	*Tetranychus exsiccator* Zehntner (mite)
Large reddish irregular blotches due to cane aphis feeding	*Aphis sacchari* Zehntner (insect)
Thrip injury	*Thrips saccharoni* Moulton (insect)
B. STREAKS OR STRIPES ON LEAVES	
Eye spot	*Helminthosporium sacchari* Butler (fungus)
Brown stripe	*Helminthosporium stenospilum* Drechsler (fungus)
Red stripe	*Phytomonas rubrilineans* Lee et al (bacterium)
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Mosaic	A filterable virus
Chlorotic streak	Undetermined
Pahala blight	Manganese or iron deficiency
Leaf variegation	Inherited characteristic
Mechanical abrasion	Mechanical friction or wind whipping
Iron deficiency	As a result of soluble calcium in the soil

C. **Wilting or Rolling of Leaves**	
Red rot	*Colletotrichum falcatum* Went (fungus)
Pineapple disease	*Thielaviopsis paradoxa* (de Seynes) v. Hohn (fungus)
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Following growth failure	(See Part VI)
Wind burn	Excessive transpiration
"Knife cut"	Undetermined
Water deficiency	Insufficient soil moisture or excessive transpiration
Iron injury	Excessive ferric iron in soil solution
Aluminum injury	Excessive soluble aluminum in soil solution
Excessive fertilization	Toxicity of applied nutrients
D. **Rotting of Spindle (Top Rot)**	
Eye spot	*Helminthosporium sacchari* Butler (fungus)
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Red rot	*Colletotrichum falcatum* Went (fungus)
Iliau	*Gnomonia iliau* Lyon (fungus)
Growth failure	(See Part VI)
Red stripe	*Phytomonas rubrilineans* Lee et al (bacterium)
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Borer injury	*Rhabdocnemis obscura* Boisduval (insect)
Banded (sectional) chlorosis	Low temperatures
Pahala blight	Deficiency of available manganese or iron
Lightning injury	Lightning
Iron injury	Excess of soluble ferric iron in soil solution
Aluminum injury	Excess of soluble aluminum in soil solution
Fertilizer burns	Fertilizers applied on foliage
Aborted tassels	Undetermined
E. **Malformation of Cane Top**	
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Bunch top	Undetermined
Twisted or tangle top	Mechanical entanglement of leaves
F. **Irregular Bands on Leaves**	
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Banded or sectional chlorosis	Low temperatures
Pale blotches on leaf near or adjoining leaf sheath	Inherited characteristic
G. **Chlorosis**	
1. **Entire Leaf**	
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Coral chlorosis (limestone)	Excessive soluble calcium
Ratoon chlorosis	Undetermined
2. **Leaves Affected in Part**	
a. Streaks	
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Mosaic	A filterable virus
Pahala blight	Manganese or iron deficiency in soil
Leaf variegation	Inherited characteristic
Chlorotic streak	Undetermined
b. Bands or blotches	
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Banded chlorosis	Low temperatures
Pale blotches on leaf blade near or adjoining leaf sheath	Inherited characteristic

H. LEAF BURNS	
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Wind burn (formerly called leaf burn)	Excessive transpiration
Fertilizer burn	Fertilizers applied on foliage
Fire injury	Fires
Salt spray injury	Wind-blown sea water
Injury from weed sprays	Chemicals
Lightning injury	Lightning
Oil injuries	Oil and grease from implements, etc.
Midrib blotch (whitish)	Undetermined
II. AFFECTING THE LEAF SHEATHS	
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Iliau (binding)	*Gnomonia iliau* Lyon (fungus)
Red rot (sclerotial disease)	*Sclerotium rolfsii* Kruger (fungus)
Phyllosticta spot	*Phyllosticta hawaiiensis* Caum (fungus)
Stem mites	*Tarsonemus spinipes* Hirst (mite)
III. AFFECTING THE STALKS	
A. EXTERNAL SYMPTOMS	
1. SPOTS OR STREAKS	
Eye spot	*Helminthosporium sacchari* Butler (fungus)
Red stripe	*Phytomonas rubrilineans* Lee at al (bacterium)
Mosaic	A filterable virus
Stem mites	*Tetranychus exsiccator* Zehntner (mite)
Mealy bug injury	*Trionymus sacchari* (Cockerell) (insect)
Sunburn	Direct sun rays
Leaf hopper egg punctures	*Perkinsiella saccharicida* Kirk. (insect)
2. EXTERNAL GROWTHS	
Stem galls	Undetermined
3. BREAKING OF RIND	
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Rind disease	*Melanconium sacchari* Mass. (fungus)
"Knife cut"	Undetermined
Borer injury	*Rhabdocnemis obscura* Boisduval (insect)
Rat injury	*Rattus* spp. (rodent)
B. MALFORMATION OF STALK	
Zigzag joints	Undetermined
Bifurcated stalks	Undetermined
Diagonal nodes	Undetermined
Budless nodes	Undetermined
Constriction of stalk	(1) *Gnomonia iliau* Lyon (fungus) (2) *Helminthosporium sacchari* Butler (fungus)
C. INTERNAL SYMPTOMS	
1. DISCOLORATION OF BUNDLES	
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Red stripe	*Phytomonas rubrilineans* Lee et al (bacterium)
Chlorotic streak	Undetermined
Root rot, advanced stage	*Pythium aphanidermatum* (Edson) Fitz. (fungus)
2. DISCOLORATION, GENERAL	
Red: decay	Injuries; mechanical, fungal, followed by secondary decay organisms
Red: red-rot type	*Colletotrichum falcatum* Went (fungus)
Black: Pineapple disease type	*Thielaviopsis paradoxa* (de Seynes) v. Hohn (fungus)

IV. AFFECTING THE ROOTS

A. FUNGOUS ROTS	
Pythium type	*Pythium aphanidermatum* (Edson) Fitz. (fungus)
Marasmius type (rare)	*Marasmius sacchari* Wakker (fungus)
B. NEMATODE INJURIES	
Red lesions	*Tylenchus similis* Cobb (nematode)
C. OTHER ANIMAL INJURIES	
Root trimming by Anomala grubs	*Anomala orientalis* (Waterhouse) (insect)
Pitting caused by springtails (most abundant)	*Isotomodes* sp. (insect)
Pitting caused by centipedes	(1) *Mecistocephalus maxillaris* (Gervais) (centipede) (2) Undetermined species
Pitting caused by snails	*Geostilbia baldwini* (Ancey) (snail)
Pitting caused by symphylids	(1) *Scolopendrella* sp. (garden centipede) (2) *Scutigerella* sp. (garden centipede)
D. MALFORMATIONS	
1. SWELLINGS AND DISTORTIONS	
Nematode galls	*Heterodera radicicola* (Greef) (nematode)
Distorted roots (and mechanical galls)	Soil structure
Excessive branching	Following injuries to growing point, chemical, biological or mechanical stimuli
E. NON-PARASITIC BLEMISHES	
Reddened roots	Exposure to light and air

V. AFFECTING THE TASSEL

A. ABORTED TASSELS	
Tassel rot	Undetermined
Bunch top	Undetermined

VI. AFFECTING THE ENTIRE CANE PLANT (GROWTH FAILURE)

A. PARASITIC ROOT ROTS	
Pythium growth failure	*Pythium aphanidermatum* (Edson) Fitz. (fungus)
Weak parasites-Marasmius type	*Marasmius sacchari* Wakker (fungus)
B. NEMATODES, AFFECTING ROOTS	
Galls	*Heterodera radicicola* (Greef) (nematode)
Lesions or punctures	*Tylenchus similis* Cobb (nematode)
C. NUTRITIONAL DISTURBANCES	
Salt injury	Excess of sodium or magnesium salts in soil
Aluminum and iron toxicity	Excess of iron and aluminum
Manganese toxicity	Excess of manganese
Unfavorable base ratio	Unbalanced calcium and magnesium ratio
Nitrogen deficiency	Inadequate supply of available nitrogen
Potash deficiency	Inadequate supply of available potash
Phosphate deficiency	Inadequate supply of available phosphate
Manganese deficiency	Inadequate supply of available manganese
Iron deficiency	Excess of calcium or manganese in soil
Water deficiency	Inadequate soil moisture
Deficiency of one or more of the less essential elements	Such as boron, copper, titanium, zinc, arsenic, etc.
Excess of any one chemical element	Excess of nutrients, ferric iron, etc.
Excess of coral in surface soil or marl in subsoil (See chlorosis under I-G)	Abnormal soil conditions

The above outline has been prepared in collaboration with plantation personnel and Station staff members with the idea of using it in a "Handbook of Sugar Cane Diseases in Hawaii," that is now being prepared. In this handbook an account will be given embracing such points as the history, description, transmission and control measures of each disease listed.

Weather and the Quality of Juice at Ewa

By U. K. Das

In our previous study (1) of the relation of weather conditions to the sugar yields of the Ewa Plantation Company, no attempt was made to segregate the influences of weather on the quality of cane apart from the tonnage or quantity of cane. In the present paper we propose to discuss specifically the relation of weather conditions to the quality of cane.

It is generally agreed that weather has a great deal to do with the quality of our cane juices. The question arises: What element or elements of the weather is it that affect the juices? Is it temperature, sunshine, rainfall or is it anything else? Again is it only the weather during the harvesting season that is of importance or the weather of any preceding period during the lifetime of the crop? We hear of such statements as cool weather improving the quality of juice or excessive rainfall depressing it. But when we try to apply these observations to actual data, we are often disappointed. These generalizations do not suffice to explain the differences in the quality of juice from one year to another. Our disappointment arises no doubt from the fact that we know so little of the physiological processes of a ripening cane. Before we can answer such questions as: Why such good juices in 1925 and why such poor ones in 1927? We need to know more and more precisely of the manner in which sucrose is accumulated in cane. The problem is, indeed, difficult; whereas we know of ways of measuring the effect of such factors as temperature, moisture, etc., on the outward processes of cane growth, we have as yet no satisfactory method of measuring the changes that take place inside the cane plant. It is this inherent difficulty that has led most of the investigators to approach this problem of juice quality in an indirect manner. That is, instead of directly measuring the effect of weather factors such as temperature, bright sunshine, etc., on juices, they have delved into the past history and tried to correlate the quality of juices with the weather conditions prevailing during the growing period of the crop. Significant relations have been established which have proved to be reasonable and sound. Our method of approach is essentially the same.

Previous Work

Browne and Blouin (2) found that in Louisiana cool weather preceding the harvesting season improved the sucrose content of cane. The more recent study of McDonald (3) confirmed the findings of Browne and Blouin. But this study also showed that super-normal mean temperature in the preceding summer and also at the beginning of the harvesting season was necessary for high sugar content. McDonald also found that excessive rainfall in the months preceding harvest was detrimental while sunshine during the same period was helpful in obtaining good juices. Koenig (4) in Mauritius found that both cool and dry weather

before harvest improved juice quality. Tengwall and Van der Zyl (5) in Java showed that the percentage of sugar from year to year was favorably influenced by excessive rainfall in the latter months of the planting year and unfavorably by excessive rainfall in the opening months of the cropping year. In Hawaii, the work of Das (6) showed that at the Pepeekeo Sugar Company, good juices were associated with dry weather in the grinding season, but with super-normal rainfall in the growing months of the previous year. The same worker also found that moderately high mean temperature during and preceding the grinding season was not only not harmful but it had a favorable influence on the sucrose content of cane. The present study is a little different from the others just cited in that it deals with the juices of an efficiently irrigated plantation, where the variations in seasonal rainfall are not likely to cause serious disturbances.

Materials and Methods

The subject of our investigation is the quality of juice (1904-1917) from a selected group of Lahaina fields. This group of fields comprises an area of about 1000 acres each year and it was shown in our previous study (1) that we have reasons to believe the averages from these fields represent the average yield of the plantation. In a latter part of this paper, the deductions from the study of 1904-1917 have been utilized to explain the differences in the quality of juice of some recent years.

The statistical methods are also the same as in our previous study. Only in the present case we have gone a step further in that we have tried to determine the influence of temperature or sunshine on sugar content by eliminating the possible influence of an interdependence of the two factors. This is known as the method of partial correlation. For the theory and development of these methods, we would refer the reader to some standard book on statistics.

Meaning of the Correlation Coefficients

A coefficient is positive (+) or negative (—) depending on whether an increase in one variable is associated with an increase or decrease of the other variable. Thus if increasing temperature increases sucrose content then we say that temperature has a positive correlation with sucrose, if on the other hand increase in temperature brings about a decrease in sucrose content, we say that the correlation between the two is negative. According to Fisher (7), where the number of items is fifteen, as in the present case, a correlation of $\pm .56$ or more is of definite significance. Some writers prefer to call the periods showing such significant correlations as periods of "critical importance." Thus, if winter temperature and sugar content has a significant correlation of $\pm .60$, we would conclude that the sugar content is influenced more by the temperature in winter than at any other period having a correlation of less than .56. Also, whereas a crop will be able to get over the good or poor conditions at other periods, it will be permanently benefited or injured by the conditions obtaining in the "critical periods."

The Average Weather at Ewa

We have records of the following weather conditions at Ewa Mill:

(1) Daily and average monthly maximum temperature.

(2) Daily and average monthly minimum temperature.

(3) Daily and average monthly mean temperature.

(4) Daily and total monthly precipitation.

(5) Number of clear and cloudy days in a month. (A clear day has over 75 per cent of the sky clear and a cloudy day over 75 per cent of the sky cloudy.)

The complete records are given in an appendix to this report. The normal for the years 1903-1917 are shown in Fig. 1. We would draw attention to the following points: (a) at Ewa, January, February and March constitute the winter months, December being warmer than March; (b) the extreme dryness of the spring, summer and fall months and insignificant amount of rain in the rainy months; (c) the unexpectedly low number of clear days in the fall months.

Quality of Juice—Definitions

By juice, in this report, we mean specifically crusher juice though we intend this term to include total juice extracted. We have two aspects of the quality in mind—namely, (a) the polarization of the crusher juice, (b) the purity of the crusher juice.* In general high polarization means high purity, but not always.

Polarization of Crusher Juice

Table I and Fig. 2 show the polarization of crusher juice of the crops of 1904 to 1917 for the selected group of Lahaina fields, as well as the average polarization of all the fields of the plantation. It will be noted that the averages of the selected fields show the same nature of fluctuation as the averages of all the fields. This fact makes us surer of the reliability of our data from the selected Lahaina fields.

Table II gives the deviations of the individual years from the mean of the odd or even years. The odd and even years are grouped separately as an additional precaution against introducing the error of field variability, for under the cultural conditions of 1904 to 1917 the same fields were harvested in the alternate years.

Temperature and Polarization

Two distinct processes are involved in the life of the cane plant. One is of assimilation, by which the plant takes in carbondioxide from the air to build up sucrose and other carbohydrates and proteins. This process goes on only at daytime under the influence of light. The other is the counter process of respiration which breaks up the assimilated material to supply the energy for many chemical changes that take place inside the plant. At night, in the dark, only the process of respiration goes on. Both of these processes are markedly influenced by tem-

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* Purity per cent $= \dfrac{\text{Pol}}{\text{Brix}} \times 100$; Thus, Purity is a measure of solids other than sucrose in the cane juice.

perature. Obviously, for an understanding of the accumulation of sucrose in cane, we would be mainly interested in the average day temperature and the average night temperature. As such records are not available at Ewa, we have taken the average maximum temperature as an index of day temperature and the average minimum temperature as an index of night temperature.

Table III gives the coefficients of partial correlation between maximum or minimum temperature and polarization. Fig. 3 is a graphic presentation of the same data. In the years 1904-1917, the average time of starting the crop was the months of July and August and the crop was in the field for nearly two years. The coefficients have, therefore, been obtained for every month during the growth period of the crop.

TABLE I

Polarization and Purity of Crusher Juice

Crop Year	Polarization of Juice Per Cent Average of All Fields	Polarization of Juice Per Cent Average of Selected Fields	Purity of Crusher Juice Per Cent Average of All Fields	Purity of Crusher Juice Per Cent Average of Selected Fields
1904	*15.5*	*15.7*	*86.6*	*86.3*
1905	*16.9*	*16.9*	*87.1*	*87.1*
1906	17.3	17.6	87.5	88.4
1907	16.5	16.7	88.1	88.5
1908	16.9	16.6	90.3	90.6
1909	17.8	18.0	91.7	92.0
1910	16 8	17.7	88.6	89.6
1911	17.7	18.2	89.4	90.4
1912	17.0	17.9	87.6	89.4
1913	16.7	17.5	87.0	88.6
1914	16.3	17.5	85.8	88.1
1915	16.5	17.5	86.0	89.0
1916	15.3	16.6	84.1	87.2
1917	15.7	17.1	85.8	88.8
1924	15.77		86 13	
1925	15.99		86.95	
1926	15.73		85.68	
1927	15 42		85.57	
1928	15.80		86.77	
1929	16.13		86.86	

TABLE II

Deviations of the Percentage of Polarization in Crusher Juice from the Mean of Odd and Even Years Respectively

	Pol Per Cent	Deviation from the Mean		Pol Per Cent	Deviation from the Mean
1905	16.9	—.5	1904	15.7	—1.4
1907	16.7	—.7	1906	17.6	+ .5
1909	18.0	+.6	1908	16.6	— .5
1911	18.2	+.8	1910	17.7	+ .6
1913	17 5	+.1	1912	17.9	+ .8
1915	17.5	+.1	1914	17 5	+ .4
1917	17.1	—.3	1916	16.6	— .5
Mean	17.4		Mean	17.1	

TABLE III

Correlation Coefficients Between Polarization and Purity of Crusher Juice and Weather Factors

	Partial Correlation Polarization and			Total Correlation Polarization and			Total Correlation Purity and			
	Mean Max. t°	Mean Min. t°	No. of Clear Days	No. of Cloudy Days	No. of Part Cloudy Days	Rainfall	Max. Temp.	Min. Temp.	No. of Clear Days	Rainfall
2 Years Ago:										
July	+.07	—**.59**	—.30					—.35		
August	+.41	—**.71**	+.39				—.08	—.15	+.26	
September	+.46	—**.67**	+.12				+.20	—.18	+.29	
October	+.47	—**.60**	+.34				+.20	—.08	—.15	
November	+.26	—.06	+**.76**				+.39	—.21	+.18	
December	+.16	+.04	+.36				+.30	+.10	+.16	
1 Year Ago:										
January	+.30	—.39	—.05				+.15	+.06	—.25	
February	+.40	—.25	—.14				+**.58**	+.14	+.32	
March	+.15	+.23	+.31				+.26	+.52	+.23	
April	—.05	—.17	+.20				+.05	—.49	+.22	
May	—.28	+.14	+.35				+.15	+.01	+.18	
June	—.22	+.06	—.12				—.06	—.04	+.03	
July	—.11	—.40	+.37	—.30			—.09	—.37	—.18	
August	+.17	—.42	+.32	—.42			—.10	—.24	+.33	
September	—.16	—.23	—.20	+.07			—.02	—.30	+.26	
October	+.42	—**.77**	+.45	+.11			+.14	—**.69**	+.14	
November	+.13	+.15	+**.63**	—.32		—.47	+.43	—.36	+**.71**	
December	—.32	—.44	+.51	—.32		—.27	+.15	—.30	+.54	—.14
Crop Year:										
January	—.44	—.25	+.46	—.43	+.19	—.32	+.18	+.00	+.29	—.24
February	+.25	—.23	—.14	+.02	+.20	—.03	+.35	+.22	—.07	—.29
March	+.43	—.53	+.28	—.20	+.04	—.50	+.21	+.23	+.23	+.02
April	+**.61**	+.10	—.33	+.05	+.15	+.07	+.34	—.10	—.05	
May	+.34	+.38	+.48	—.45	+.28	—.04	+.44	+.15	+.34	
June	+.15	+.41	—.36	—.10	+.51					
Significance	.58	.58	.63	.60	.60	.55	.55	.55	.60	.55

Discussion

In Fig. 4, free-hand curves are presented which show in a simple manner the trend of correlation coefficients. These curves also indicate the relative seasonal needs of maximum and minimum temperature for high polarization in cane. Incidentally, these help us to understand the way in which sucrose is accumulated in a crop.

From the same figure we see that maximum temperature has a positive correlation with sugar content in the fall and winter months of the first season, negative correlation in the second season summer and in the months immediately before harvest, and positive relation again in the harvesting months. This means that to get high polarization we should have maximum temperature super-normal in the first season, sub-normal in the summer and winter months of the second season and super-normal again in the harvesting season. Now maximum temperature is an index of day temperature and it is during the daytime that the vital process of photosynthesis and assimilation goes on. High maximum temperature means favorable conditions of assimilation and growth during the daytime. Therefore, it is easy to see why high maximum temperature should be essential in the first season for it is at this time that cane plants are young and growing at a fast rate, sending out new shoots and building that spacious store-house of cells where sucrose is to be accumulated later on.

In the second season summer, the crop is already well advanced; if the summers are too hot at this time vegetative growth may continue at a rapid rate and very little sucrose accumulate in the cane. Also it is probable that in an arid place like Ewa, excessive heat tends to increase the concentration of soil solution and, thereby, cause greater absorption of non-sugars by the cane plant. The work of Row (8) in India and Thieme (9) in Java show that a high percentage of non-sugars in the cane is associated with low sucrose content and low purity of juice. The need of cool weather in the late fall and early winter months is in agreement with the popular saying that "cool weather sweetens the cane." Cool weather decreases vegetative activity and gives the plant a chance to start accumulating sugar.

Again there is need for high maximum or day temperature in the harvesting season. Whether the effect of high temperature at this period is of any physiological significance we do not know. Yet it is conceivable that the changes in the concentration and acidity of the juice as the cane plant approaches the harvesting stage, together with high maximum temperature may accelerate the activity of certain enzymes that are helpful to sucrose accumulation. Also, high maximum temperature at this stage may slightly increase the concentration of juice by bringing about a reduction in the percentage of moisture in the cane. Verret and others (10) found a reduction of 2 to 3 per cent in moisture in mature cane from which irrigation water had been withheld for 60 to 90 days. In Table III we see that there is only one period of "critical significance," the month of April of the cropping year, which would indicate that warm days are very necessary in this period.

The coefficients of minimum temperature are almost all negative, which means

that for high polarization in cane minimum temperature should always be below normal. In other words, as minimum temperature is an index of night temperature, for high polarization in cane the nights should be always cool. Undoubtedly that is why places where the fall in temperature is great at night, have been observed to produce sweet canes. Why are low night temperatures so essential for high sugar content? The beneficial effect of low night temperature is explained this way. At daytime the plant gains by assimilation and it loses part of it at night by respiration, so that the total gain of matter to the plant may be represented by an equation. Total gain of matter = Total matter assimilated — matter lost by respiration. It is obvious, therefore, that assimilated material being the same the greater the loss by respiraion the less is the gain to the plant. High night temperatures increase the respiratory activity of the plant thus inducing great losses of assimilated matter. The following figures from Lundegardh are quoted by Blackman (11) to show the effect of increasing temperature on the hourly loss, by respiration at night, from one hectare of potato field:

RESPIRATION LOSS PER HOUR PER HECTARE

Temperature	0°	5°	10°	15°	20°	25°
Losses (Kilogramme)	0.45	1.0	1.5	2.0	3.0	4.5

A second table from the same source (11) gives the assimilation and respiration of an oat field at two night temperatures.

ASSIMILATION AND RESPIRATION PER HECTARE

Assimilation	Respiration	Gain
300 K. grams	175 Kg. (20° C.)	125 Kg. (330-175)
300 K. grams	132 Kg. (10° C.)	168 Kg. (300-132)

Thus, a difference in temperature of 10° C. at night made a difference of over 30 per cent in the total weight of matter gained by the oat field. In sugar cane, most of the matter gained is stored in the form of sucrose and it is clear from the foregoing that low night temperature will increase the amount of sugar in the plant, conditions of assimilation being the same.

That sugar cane is not the only plant to show such temperature relationship is proved by the work of Gregory (12) on barley. Gregory found that the net assimilation rate had significant positive correlation with day temperature and negative correlation with night temperature.

Obviously the ideal condition would be high day temperature and other favorable growing conditions by day and low night temperature by night. That such is actually the case with sugar cane for a considerable period of its growing time is shown by the simplified curves of Fig. 4. As regards minimum temperature, two periods appear to be significant or of critical importance. These are the first few months after starting in the first season of the crop and the fall months of the second season, especially the month of October preceding harvest.

That cool nights are necessary in the months just before harvest will be generally agreed to, for that is the time when the crop as a whole is slowing down growth and entering into the ripening stage. It is in this period that the crop should be extremely susceptible to favorable ripening weather.

The great need of cool nights and, as we have previously noted, of warm days in the first season point again to the conclusion that in the life of a sugar cane crop the first few months are of the utmost importance.

For optimum conditions the days should be warm and the nights cool in the first season. This may mean that the cane plant benefits by a big range in temperatures in the first season. Harrington (13) and Morinaga (14) have shown that alternating high and low temperatures hasten the germination of seeds and bulbs. If the buds of sugar cane react as favorably towards a great range of temperature, then we are likely to have earlier suckering, which would mean a greater number of mature stalks at harvest and hence a higher sucrose content.

Also, for the best development of certain higher plants a great range of temperature is essential, whether the sugar cane is one of them we do not know.

Number of Clear Days and Polarization

It is generally known that some plants grow well in shade and that others require plenty of sunlight for maximum development. The tropics being the natural habitat of the sugar cane, it would seem reasonable to assume that the cane plant also will thrive best when there is an abundance of sunshine and clear days. That such is actually the case at Ewa is borne out by our studies.

In the absence of data on the actual hours of sunshine, the number of clear days may be taken as a good index of the condition of light.

Table III and Fig. 5 show that the coefficients of correlation between clear days and polarization are almost always positive. This means that we are likely to have high polarization at Ewa when the amount of sunshine is more than normal throughout the growth of the crop. Therefore, there is more truth than poetry in the saying that "sugar is crystallized sunshine."

There are two periods of "critical importance"—the fall months of the first season, specifically the month of November and the fall months just prior to harvest, particularly again the same month of November. We believe that the "critical importance" of an abundance of clear days in the first season is due to the fact that this abundance promotes early suckering. Verret and McLennan (15) in Hawaii, Brenchley (16) in England have shown definitely that the plants receiving more sunlight have always a greater number of early and vigorous suckers. The investigations of Rodrigues (17) prove that early suckering is closely associated with high sugar content of a cane crop. As we have said once before, early suckering means a greater number of mature stalks at harvest and consequently the average sucrose content for the crop is higher.

There is not much need indicated for an extra amount of sunlight in the second season spring and summer, possibly because Ewa's normal of twenty-five clear days per month in those seasons is enough anyway.

The "critical importance" of sunshine in the second season fall months is easily understandable. The normal for Ewa at this season is rather lower than we should expect (Fig. 1) and it is at this period that the crop is entering into the ripening stage and therefore needs all the sunshine it can get so that it can elaborate a greater amount of sugars.

We also worked out a few coefficients of correlation between cloudy days and sugar content and part cloudy days and sugar content. It is significant that the coefficients of cloudy days are generally negative and those of part cloudy days slightly positive. This entirely confirms what we have said about a large number of clear days being essential for high sugar content.

Temperature and Purity

The average purities for the selected group of Lahaina fields are to be found in Table IV and Fig. 6.

The coefficients of total correlation between maximum temperature and purity, and between minimum temperature and purity are given in Table III and Fig. 7.

The coefficients indicate that purity is influenced by maximum temperature in the different months in about the same way as polarization is. For high purity there is need for super-normal maximum or day temperature in the first season summer and super-normal temperature again in the fall and winter months preceding and during harvest. Only one month, the month of February in the first season, is significant.

Great interest attaches to the steady decline in the values of the coefficients from the first season February on until the value becomes definitely negative in the summer months and continues to be so until September of the second season. The harmful effects of high day temperature are to be explained by the fact that high temperature causes greater absorption of non-sugars. It is also of interest that need is indicated for super-normal day temperature in the fall months before harvest.

TABLE IV

Deviations of the Percentage of Purity of Crusher Juice from the Mean of Odd and Even Years Respectively

	Purity Per Cent	Deviation from the Mean		Purity Per Cent	Deviation from the Mean
1904.......	86.3	— 2.2	1905.......	87.1	— 2.1
1906.......	88.4	— .1	1907.......	88.5	— .7
1908.......	90.6	+ 2.1	1909.......	92.0	+ 2.8
1910.......	89.6	+ 1.1	1911.......	90.4	+ 1.2
1912.......	89.4	+ .9	1913.......	88.6	— .6
1914.......	88.1	— .4	1915.......	89.0	— .2
1916.......	87.2	— 1.3	1917.......	88.8	— .4
Mean	88.5		Mean	89.2	

TABLE V

Number of Clear Days This Year and the Average Purity of Crusher Juice in the Crop Harvested Next Year (i. e. Number of Clear Days in 1907 and the Purity of Juice for the 1908 Crop)

Crop of	No. of Clear Days Previous Year	Purity of Juice Per Cent All Fields	Crop of	No. of Clear Days Previous Year	Purity of Juice Per Cent All Fields
1908.........	209	90.3	1919.........	119	86.4
1909.........	225	91.7	1920.........	151	83.1
1910.........	198	88.6	1921.........	116	83.9
1911.........	189	89.4	1922.........	115	86.6
1912.........	202	87.6	1923.........	73	84.6
1913.........	236	87.0	1924.........	117	86.13
1914.........	191	85.8	1925.........	170	86.95
1915.........	184	86.0	1926.........	154	85.68
1916.........	166	84.1	1927.........	129	85.57
1917.........	157	85.8	1928.........	81	86.77
1918.........	148	85.2	1929.........	98	86.59

The coefficients of minimum temperature again indicate the need for cool nights for a considerable period of the growing time of a crop. The periods of "critical importance" are, of course, the fall months prior to harvest, especially the month of October. It is of interest that the first season months are not as significant as regards high purity as they were in the case of high polarization. The explantation may be that we cannot begin to think of purity of juice until sucrose has begun to be stored in any appreciable amount in the cane plant, which would, normally, be in the second season.

Number of Clear Days and Purity

The correlation coefficients (Table III, Fig. 8) indicate the need of brighter days throughout the entire life of the crop. As polarization and purity are closely correlated, this would almost follow from what we found to be the relation of clear days and polarization.

Here again it is not the first season that is of much importance to high purity, but the fall months of the second season, particularly the months of November and December preceding harvest.

Fig. 9 shows the close relation between purity of crusher juice at Ewa and the number of clear days in November before harvest. Table V and Fig. 10 show that the fluctuations in the purity of juice from year to year bear a definite relationship to the number of clear days in the year preceding harvest, which will be the year 1905 for the crop of 1906. That such would be the case would follow from the curve of "theoretical optimum" Fig. 8 (B).

Rainfall and the Quality of Juice

We have not thus far considered rainfall not because we do not consider it of great significance, in fact in some localities it is the most important factor in cane ripening, but, because at Ewa the cane is sought to be ripened artificially by with-

holding irrigation water and that rainfall in the grinding season does not amount to enough to be of possible significance. To verify our point, we have worked out the coefficients of correlation beween polarization and rainfall, Table III. The coefficients are all negative, and not one is significant. In other words, supernormal rainfall immediately before and also during the harvesting season, is not favorable to obtaining high polarization, but this is a factor of minor importance under the conditions of Ewa.

Quality of Juice in Some Recent Years

The investigations presented so far in this paper considered the quality of juice of a selected group of Lahaina fields from 1904-1917. If our deductions are sound in principle then, we should be able to apply them to the quality of juice of variety H 109 and explain in a general way why such good juices in 1925 and such poor ones in 1927. Cultural practices have been the same for both of these years, but the crusher juice in 1925 had a polarization of 15.99 per cent and purity of 86.95 per cent, and that of 1927 a polarization of 15.41 per cent and purity of 85.57 per cent.

In Fig. 11, we have compared the conditions of minimum or night temperature during the growing time of the crop of 1925 and 1927. The "theoretical optimum" as deduced from our study is also presented. It will be seen clearly from these curves that 1925 had a much better weather for high quality cane than 1927.

Curves in Fig. 12 show the conditions of light for the crops of 1925 and 1927. Comparing the conditions in the two years, with the "theoretical optimum" curve, there is again no question as to why 1925 was a year of better juices than 1927. Our previous deductions are thus proved to be entirely sound.

Practical Applications

At this point some of us might ask: What is the good of all this? We will agree that we need cool nights and bright days for high sucrose, but we cannot make them to order. So, we might just as well lie back and let nature take its course. But surely we cannot be so helpless. There is a saying: "If the mountain does not come to Mahomet, Mahomet must go to the mountain." If we cannot change our weather we can surely imitate the way it works; we may try to create the same conditions of growth as good weather does. In the following pages we explain our view point.

"Critical Importance" of the First Season of Growth

We have seen that the effects of both day and night temperatures are very marked in the first season. As a result of this and our previous studies (1), (6), we have come to look upon the first season as the most important season in the life of our sugar cane crop. Clarke's (18) observations in India also point to the same conclusion. It is at this time that the crop is growing at a fast rate, new suckers are being formed, a stand is being made; it is at this time that the foundations of a good crop are being laid. While a crop reflects all the benefits of a

favorable growing condition at this time, it "never forgets and hardly ever forgives the bad treatment it has received."

Our cultural practices should be such as to give the very best care, water, fertilizer, etc., to the young crop. The growing practice of bringing water to the ratoons and starting them soon after harvest is, therefore, a move in the right direction.

Promote Early Suckering

We have said that the effect of clear days in the first season is to promote early suckering. We have cited the work of Rodrigues (17) to prove that early suckering means high sucrose content. Here, we shall explain in detail why we consider early suckering to be so important.

The curve (B) in Fig. 13 has been prepared from some growth measurement data at the Paauhau Sugar Plantation Company.* Here is shown the volumetric rate of growth at various ages of cane growing under actual field conditions. It will be noted that cane less than twelve months old is still growing at a fast rate.

Curve (A) in Fig. 13 has been prepared from the growth Experiment "E" at Waipio. The averages are for cane planted at different seasons of the year. We see from this curve that the Quality Ratio or theoretical tons cane per ton sugar improves with age up to twenty-four months. We also note that cane less than fifteen to twelve months old has a tremendously poor juice.

From considerations of curves A and B in Fig. 13 it will be obvious that if we have a large number of young suckers, growing at a fast rate and having a poor juice, included in our crop, the average quality ratio will be very poor. In Table VI data are produced from two experiments at the Paauhau Sugar Plantation Company. In one case, Field 14B was harvested at 21 months and had 19 per cent of the stalks below 15 months age; in the other case, Field 4A harvested at 24 months only 4 per cent were less than 15 months old at harvest. Under such circumstances, other conditions being similar, we are likely to get better juices from a field whose average "stalk-age" is greater than another whose stalk-age is lower. We have used this term stalk-age to denote the average age of all the stalks in a crop, and this term by itself affords an excellent index by which to judge the ripening of a field. In Table VI we see that in the Paauhau field harvested at 24 months, the stalk-age was only 21 months, in the case of one harvested at 21 months the stalk-age was only 18. Can we not gather data from the plantation fields that will indicate the age of the average stalk and do it as a form of agricultural control?

It follows from the foregoing that in order to get good juices, we should not have any stalk in our crop that is less than 15 to 12 months old. In other words, we must promote early suckering and once having obtained the suckers we should try to prevent new shoot growth in the second season. Stubbs (19) was one of the pioneers with this point in view.

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* We are indebted to the manager of the Paauhau Sugar Plantation Company for allowing us permission through R. J. Borden, to make use of the data.

TABLE VI

Paauhau Sugar Plantation Company

Growth Experiment—Number and Proportion of Stalks of Various Ages Included in the Harvest of the Experimental Fields

Field 14½-B—Irrigated, Ratoons of D 1135. Harvested at 21 Months. May, 1927.
Field 4-A—Irrigated, Ratoons of D 1135. Harvested at 24 Months. February, 1927.

Age at Harvest	Field 14½-B No. of Stalks Harvested	Per Cent of Total Number Harvested	Field 4-A No. of Stalks Harvested	Per Cent of Total Number Harvested
24			86	46
23			..	
22			1	0.7
21	93	48	..	
20	..		18	11
19	..		..	
18	..		49	26
17	20	12	..	
16	..		24	12
15	37	21	..	
14	..		5	1
13	35	12	..	
12	..		10	3
11	23	7	..	
Total stalks harvested.....	208	100	193	100
Average age of stalks.....	17.1 months		20.1 months	

In this connection experiments are in order on two subjects:

(1) What is the stooling habit of H 109 or any other standard cane? If A is the mother stalk and B and C the daughter and grand-daughter stalks respectively, then, what would be the formula for an average stool of H 109 in the field? Is it A + YB or it is A + YB + ZC? We should also know at what age or at what stage of development of the mother plant the secondaries or tertiaries develop. We know that some canes, such as the wild Saccharum, send out new shoots continuously, others stool early and still others stool late. A knowledge of the stooling habit of our standard canes will enable us to determine what practices to follow to encourage early and discourage late suckering.

(2) We should know what effect second season fertilization has on second season suckering, and on the quality of juice. Personally, we consider that our fertilizer practice in its relationship to increased vegetative growth and suckering needs careful scrutiny. Of recent years the application of commercial fertilizers per acre, especially of nitrogen, has increased considerably, while at the same time the average age of our crop has been decreasing. To our mind, this fact alone may account for the gradual decline in the quality of our juices. From physiological considerations, as we give more plant food to our crops, as we increase vegetative growth, we need to allow more time so that active vegetative growth may cease and ripening begin.

Other points that should be considered in this connection are:

(A) Planting material or seeds for the plant field: Should we treat our seeds

so that we may stimulate germination and early growth? Will it not be found profitable to have seed nurseries, the same as they have in Java?

(B) Spacing: If more space in between the rows means more sunlight and if sunlight promotes suckering, should we reconsider our present practice of spacing, keeping in mind the considerations set forth in this paper and also the cultural conditions of today?

Need for Greater Knowledge of the Physiology of Sugar Cane

This study has impressed on us in a very forcible manner the need for greater light on the obscure physiological processes that go on inside the cane plant. For a proper understanding of the influence of environment on sugar cane, for a more intelligent appreciation of its needs, for larger yields, we must have a better grasp of the fundamental principles governing the life processes of the sugar cane.

Summary

The following are presented as a summary of this paper:

A. At Ewa, cane juice of high average quality for the crop will result when weather conditions pertaining thereto are as follows:

(1) The days warmer than normal in the first season, cooler than normal in the second season summer and the late fall and winter months, and warmer again in the spring months of the cropping year.

(2) The nights always cooler than normal, especially so in the first season and in the months preceding harvest.

(3) A large proportion of clear days throughout the crop, especially so in the fall months of the first season and in the months preceding harvest.

(4) Rainfall during the harvesting season below normal, but this factor is not as important as the others just enumerated.

B. References are made to problems demanding study and suggestions are offered as to the ways in which the deductions from this weather study may be made use of in the field.

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APPENDICES

EWA PLANTATION COMPANY

APPENDIX A

Monthly Mean Maximum t°

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1901	79.4	77.5	81.4	85.9	85.7	86.7	86.6	87.7	86.5	85.6	82.6	81.2
1902	82.9	78.4	78.2	80.7	81.4	84.0	85.4	86.1	86.0	84.8	81.0	79.0
1903	78.0	70.6	78.0	81.0	83.6	85.0	86.0	86.7	85.8	83.0	81.5	80.7
1904	79.2	75.7	76.3	78.4	82.0	82.9	84.5	85.0	85.2	81.6	78.1	77.5
1905	73.5	75.4	76.1	77.7	79.8	81.5	82.4	82.4	81.9	80.1	79.0	75.6
1906	74.4	76.1	75.7	82.7	84.2	85.8	86.5	86.9	87.1	86.2	83.6	80.3
1907	80.1	80.0	78.6	80.9	84.4	85.9	86.1	86.2	87.0	85.0	82.4	81.5
1908	79.3	80.1	79.6	80.9	83.6	84.3	85.1	86.0	85.4	84.1	82.5	79.2
1909	78.2	78.4	77.0	80.5	83.3	85.4	85.4	86.1	86.3	84.8	83.5	80.1
1910	77.6	78.8	81.0	80.5	82.6	84.0	85.7	86.1	85.6	84.1	81.9	79.3
1911	76.8	77.9	79.5	82.2	83.7	84.6	85.8	87.7	85.7	84.1	82.2	79.7
1912	79.1	79.3	78.6	82.0	84.1	85.1	86.6	87.7	87.4	86.0	82.5	81.1
1913	80.6	79.3	81.5	82.8	83.5	85.2	87.5	88.2	87.7	86.8	83.1	81.2
1914	77.9	80.6	79.5	82.0	83.5	86.1	86.5	88.2	86.5	86.2	82.3	78.8
1915	77.9	77.4	80.2	81.4	84.9	87.0	87.4	88.5	87.9	85.4	81.4	79.3
1916	77.7	80.4	80.1	82.1	82.4	83.4	84.6	84.3	84.4	83.5	81.3	78.8
1917	78.2	78.3	78.9	80.9	83.4	84.7	86.1	86.5	86.7	85.3	82.6	80.6
Avg. 1903-1917	77.9	78.2	78.7	81.1	83.3	84.7	85.7	86.4	86.0	84.4	81.9	79.6
1918	80.6	78.9	78.6	78.2	82.4	84.1	86.0	86.3	86.4	86.4	83.2	79.6
1919	78.6	80.0	80.0	82.1	83.7	86.0	86.6	87.5	86.6	85.3	83.5	81.2

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1920	79.3	81.2	81.1	82.0	84.6	85.5	86.1	87.2	87.5	86.1	82.8	80.2
1921	78.3	80.8	81.2	82.4	83.9	86.9	86.9	86.7	86.4	84.3	82.2	80.3
1922	79.3	78.2	80.4	82.6	83.1	85.6	87.1	86.7	86.5	85.0	82.8	82.3
1923	78.9	79.6	80.3	82.9	85.2	86.8	87.6	88.5	87.9	87.2	83.6	80.3
1924	79.7	81.3	81.3	81.4	84.5	85.7	86.8	86.9	87.3	85.6	83.0	81.7
1925	81.5	84.0	81.8	81.2	83.4	84.6	86.0	86.5	86.4	86.1	83.2	81.5
1926	80.8	81.0	82.1	80.8	84.8	85.7	87.5	87.5	87.4	85.6	83.0	81.9
1927	80.0	81.0	80.9	82.6	84.1	86.0	83.4	86.8	87.2	85.2	81.9	80.3
1928	78.8	80.0	81.5	83.3	83.6	85.8	86.4	86.9	86.8	85.3	82.3	80.3
1929	78.8	79.6	81.2	83.7	84.2	86.2	87.7	88.0	87.8	85.9	82.0	79.1
1930	78.7	81.5	79.9	81.2	84.5	86.3	87.2	87.4	87.1	86.3	84.0	....

APPENDIX B

Monthly Mean Minimum t°

1901	67.0	65.2	68.1	68.9	68.5	69.1	69.4	70.6	68.7	68.6	67.1	64.8
1902	62.6	62.5	67.2	64.2	66.7	69.5	70.4	72.0	69.8	67.5	67.0	63.0
1903	61.0	60.0	58.0	65.0	66.4	67.0	71.0	70.9	69.7	68.0	65.3	64.2
1904	64.2	62.7	63.7	65.6	64.2	66.7	67.6	68.7	68.2	67.7	64.1	64.2
1905	55.9	57.3	58.6	62.6	65.7	66.3	68.8	70.4	69.2	67.0	65.8	61.7
1906	61.0	59.9	59.0	64.7	64.6	69.2	69.4	70.5	69.2	68.7	65.3	64.8
1907	64.5	62.2	63.0	61.6	65.1	67.8	68.5	71.2	70.1	67.6	66.2	63.9
1908	61.1	61.8	63.9	63.7	66.0	66.2	67.0	67.9	66.9	65.7	62.5	63.1
1909	60.1	61.3	63.6	62.9	65.4	68.6	69.5	68.2	67.6	67.1	64.0	63.5
1910	62.2	60.1	63.1	64.0	64.6	67.3	67.3	67.9	67.4	66.5	65.8	61.9
1911	62.6	61.6	62.4	65.2	66.2	68.2	69.9	70.7	69.9	66.1	65.1	64.2
1912	61.4	62.0	60.7	64.6	65.6	66.9	68.5	79.5	69.2	69.0	65.4	66.1
1913	62.4	59.9	62.7	65.3	65.6	67.5	68.3	....	69.0	68.1	66.9	61.9
1914	60.6	59.8	61.3	63.6	65.7	68.0	70.1	71.5	71.5	68.1	65.9	61.7
1915	60.7	61.1	61.3	62.8	66.0	68.5	69.8	71.1	69.7	68.7	67.1	65.0
1916	62.6	62.3	64.2	65.1	66.7	67.4	68.0	67.3	67.7	67.4	66.5	63.4
1917	60.4	60.2	63.4	63.7	64.4	66.5	67.2	68.0	67.3	65.9	65.2	63.2
Avg. 1903-1917	61.4	60.8	61.9	64.0	65.5	67.5	68.7	69.6	68.8	67.4	65.4	63.5
1918	61.5	61.9	61.3	63.8	63.8	66.6	69.5	69.2	67.5	68.2	64.1	63.7
1919	59.2	61.3	60.8	63.3	64.5	66.6	68.4	69.2	66.7	66.1	63.4	61.0
1920	59.7	59.6	61.7	62.7	63.5	63.9	68.4	68.6	68.0	66.6	63.4	62.9
1921	63.1	59.9	61.1	63.1	62.8	67.4	67.3	67.5	67.3	64.5	63.2	63.0
1922	61.1	60.9	61.2	63.2	63.1	64.1	65.5	66.3	66.0	64.7	62.4	59.3
1923	62.5	56.8	60.4	62.2	63.3	63.9	66.6	66.5	66.3	64.4	62.8	61.5
1924	55.2	58.7	58.7	60.7	62.5	62.7	65.1	65.0	64.2	64.3	61.5	59.5
1925	62.1	59.3	59.5	61.7	62.2	63.9	64.9	65.5	62.6	62.4	62.4	62.3
1926	61.0	61.2	61.3	61.0	66.3	67.1	68.0	68.2	68.4	66.9	63.6	64.2
1927	62.2	60.9	64.3	64.1	66.0	67.3	66.0	67.9	67.3	65.8	65.9	63.4
1928	61.7	58.7	61.0	63.6	64.5	65.2	67.6	68.0	66.6	65.6	64.0	62.9
1929	59.2	60.8	62.1	63.9	64.2	66.3	66.5	68.0	68.1	67.5	65.0	61.8
1930	59.3	60.4	62.0	62.1	64.6	66.2	68.5	70.2	69.3	66.3	63.7	....

APPENDIX C

No. of Clear Days

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1906..........								22	18	13	9	10
1907..........	6	20	10	19	20	25	20	20	18	16	14	21
1908..........	17	13	11	18	19	22	22	21	20	20	21	21
1909..........	15	9	13	11	22	20	20	26	18	17	..	11
1910..........	11	12	22	15	15	14	22	23	6	16	17	..
1911..........	9	13	14	15	19	25	21	22	14	11	18	21
1912..........	19	14	9	22	26	20	25	22	22	22	19	16
1913..........	19	15	11	20	20	21	18	10	11	13	11	22
1914..........	7	8	5	15	20	26	31	20	11	21	7	13
1915..........	28	13	9	3	14	18	21	19	7	17	4	13
1916..........	1	8	15	15	15	22	24	17	14	11	11	4
1917..........	7	10	10	18	8	21	23	18	16	9	3	5
Avg. 1903-1917.	13	12	12	16	18	21	22	20	15	16	12	14
1918..........	2	0	0	2	16	14	21	13	16	12	12	11
1919..........	12	9	8	12	20	10	13	26	7	11	11	12
1920..........	9	12	2	12	17	15	13	9	19	2	4	2
1921..........	0	9	14	16	5	23	14	10	11	8	3	2
1922..........	0	2	7	5	9	5	13	6	5	3	6	12
1923..........	2	1	5	12	20	19	26	17	4	6	3	2
1924..........	17	13	12	3	19	14	18	26	24	7	8	8
1925..........	16	11	7	7	24	21	19	22	9	9	4	5
1926..........	13	7	15	10	19	5	18	12	10	4	12	4
1927..........	5	6	2	5	3	18	6	8	19	7	2	0
1928..........	13	8	6	11	8	8	7	19	12	0	0	6
1929..........	18	6	11	1	9	18	15	11	9	7	2	13
1930..........	..	6	..	12	31	21	20	8	8	..	..	..

Fig. 1

Ewa Plantation Co.

Average Monthly Weather Conditions at Ewa Mill.

(Ave. 1903-1917)

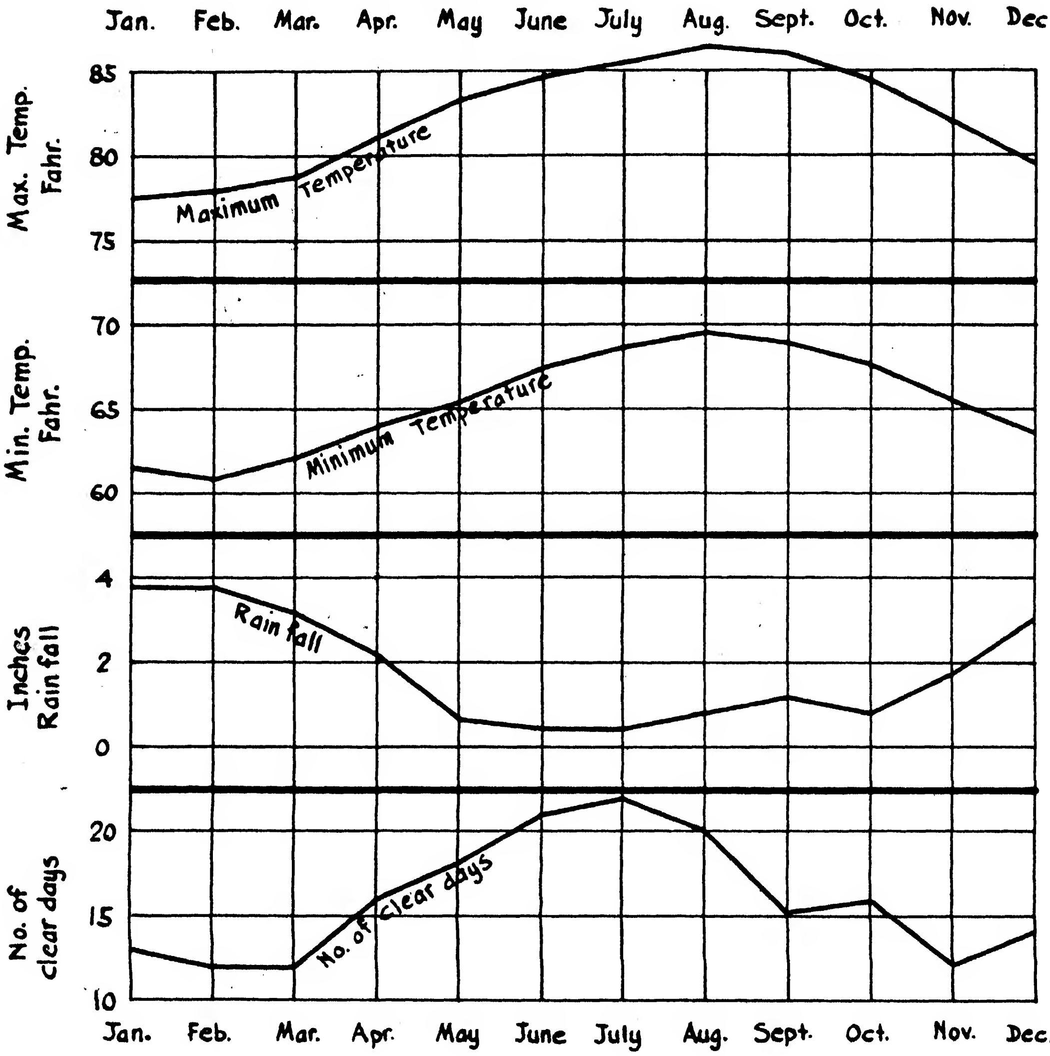


Fig. 2

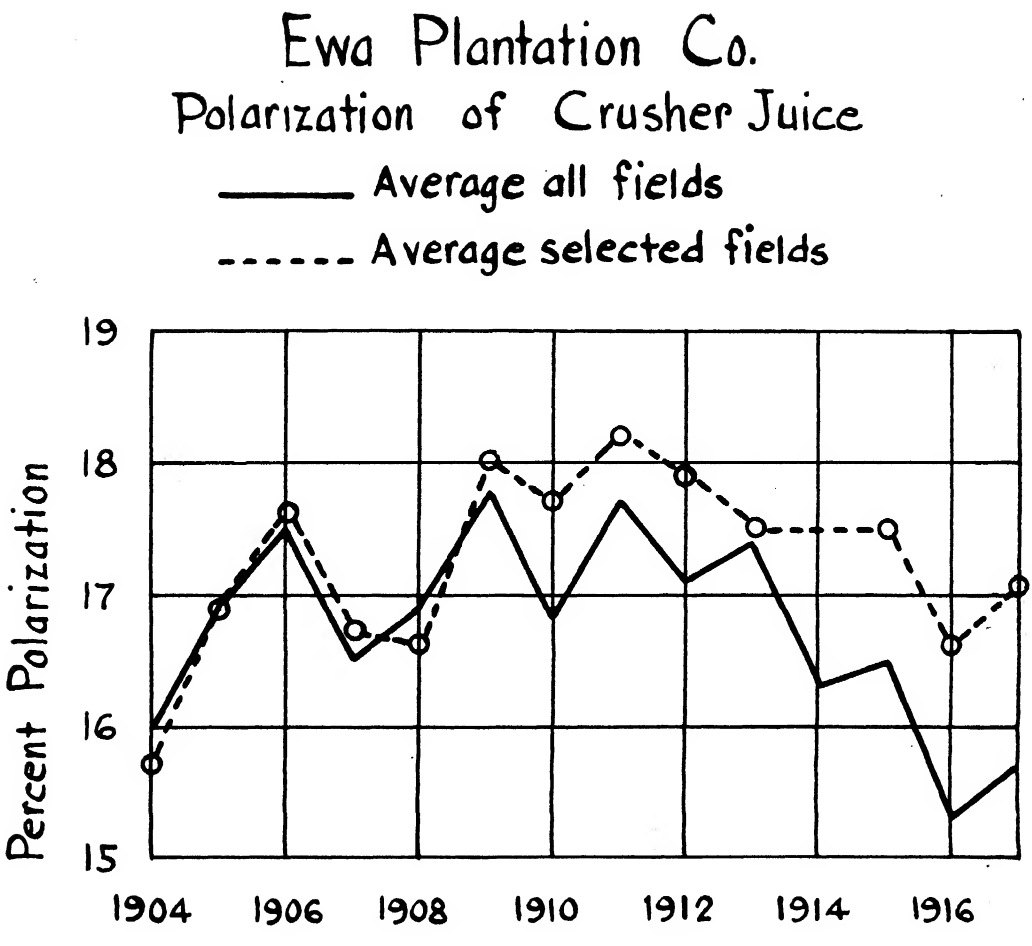

Ewa Plantation Co.
Polarization of Crusher Juice
Average all fields
Average selected fields
Percent Polarization
19
18
17
16
15
1904
1906
1908
1910
1912
1914
1916

Fig. 3

Ewa Plantation Co.

Co-efficients of Correlation between Polarization of Crusher Juice and (A) Mean monthly maximum temperature (B) Mean monthly minimum temperature

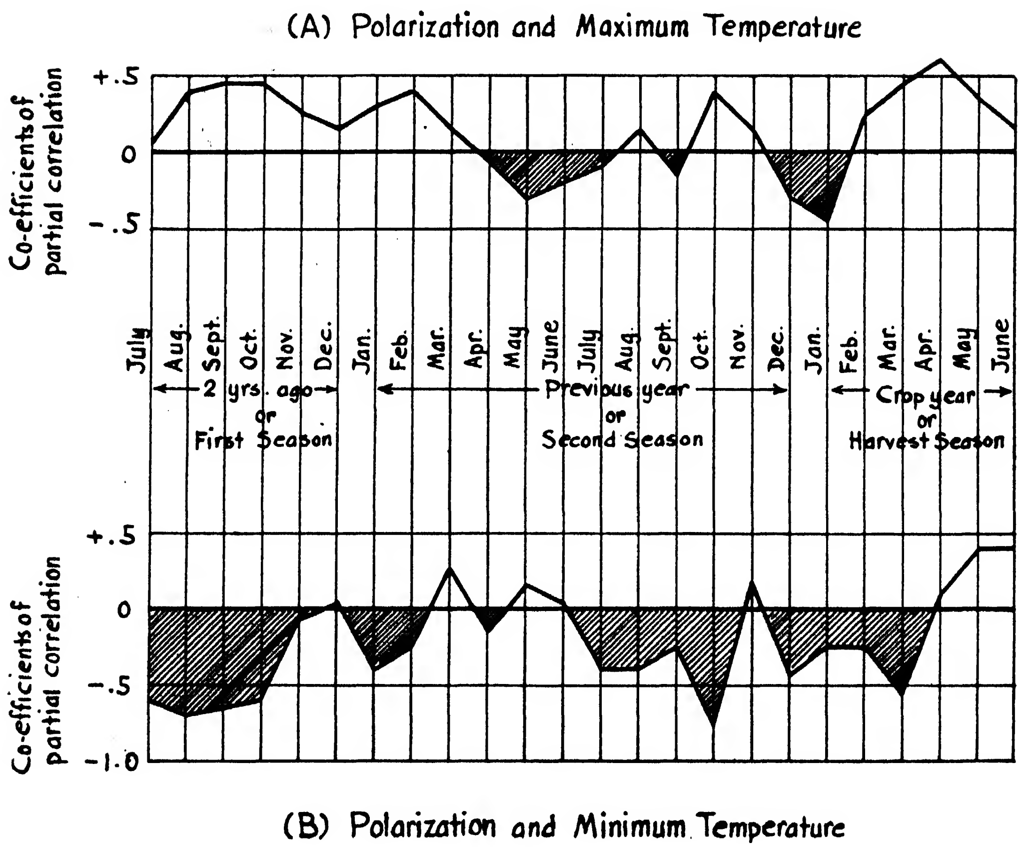


Fig. 4

Ewa Plantation Co.

Seasonal Temperature Conditions Essential For High Polarization Of Juice As Interpreted From The Trend Of Values Of Correlation Co-efficients

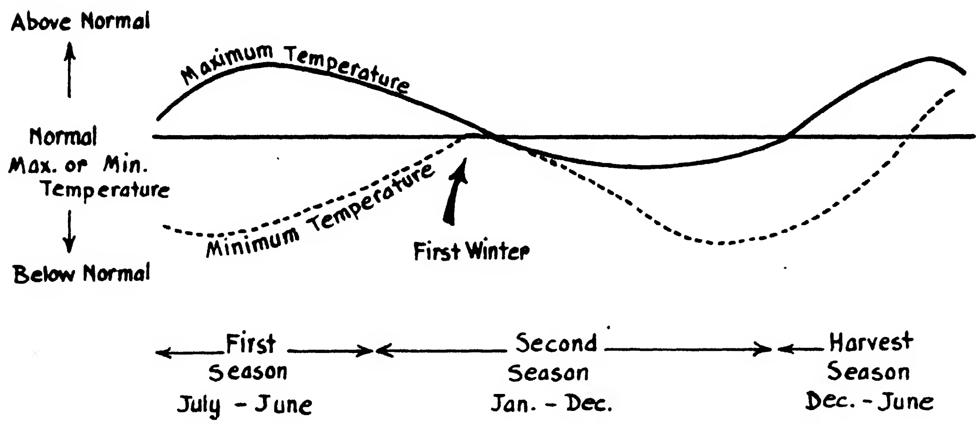


Fig. 5

Ewa Plantation Co.

Co-efficients of Correlation between Polarization of Crusher Juice and (A) Number of clear days in a month (B) Number of cloudy days in a month

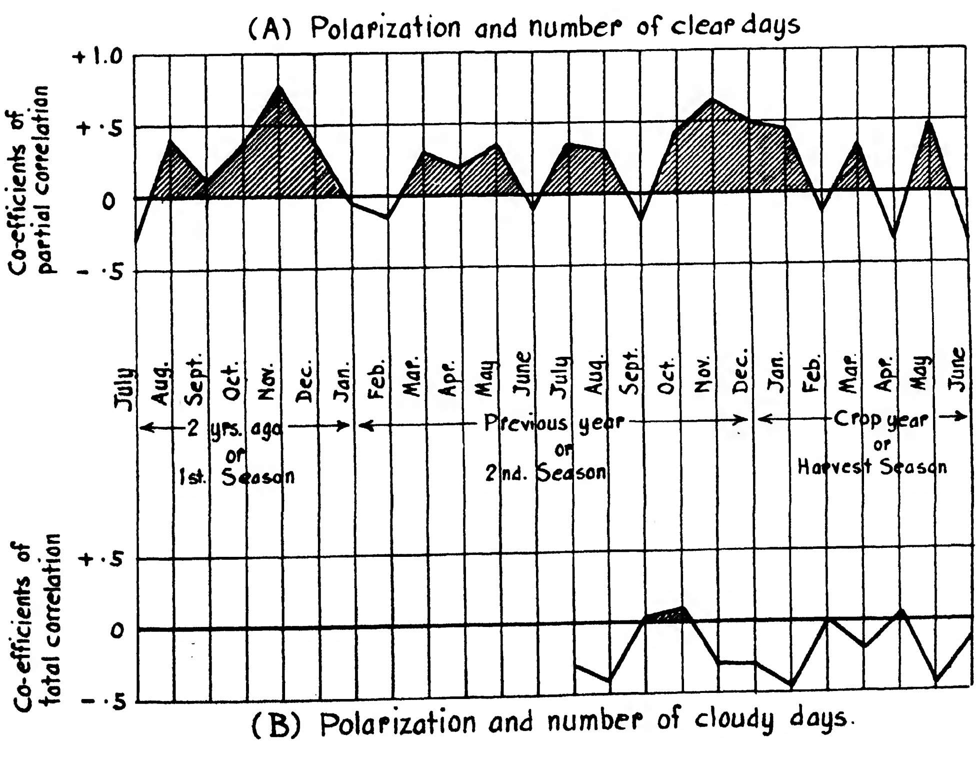


Fig. 6

Ewa Plantation Co.

Purity of Crusher Juice of Selected Lahaina Fields Compared to the Average Purity of All the Fields of the Plantation.

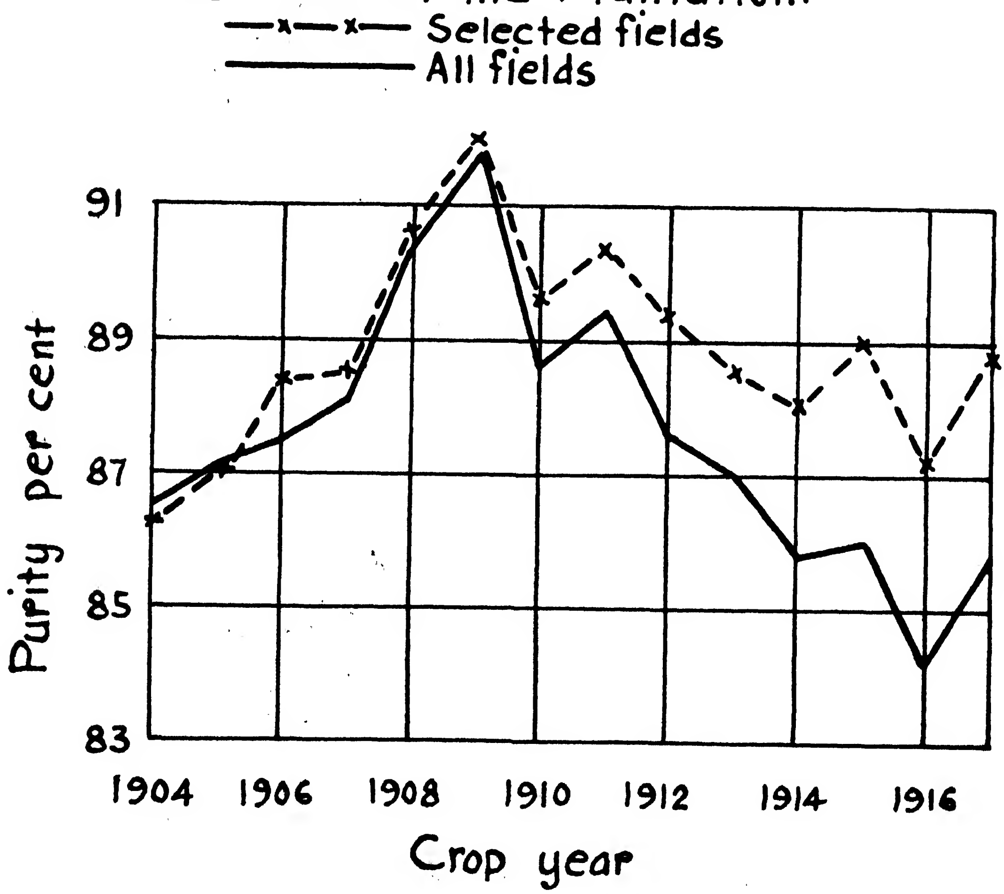
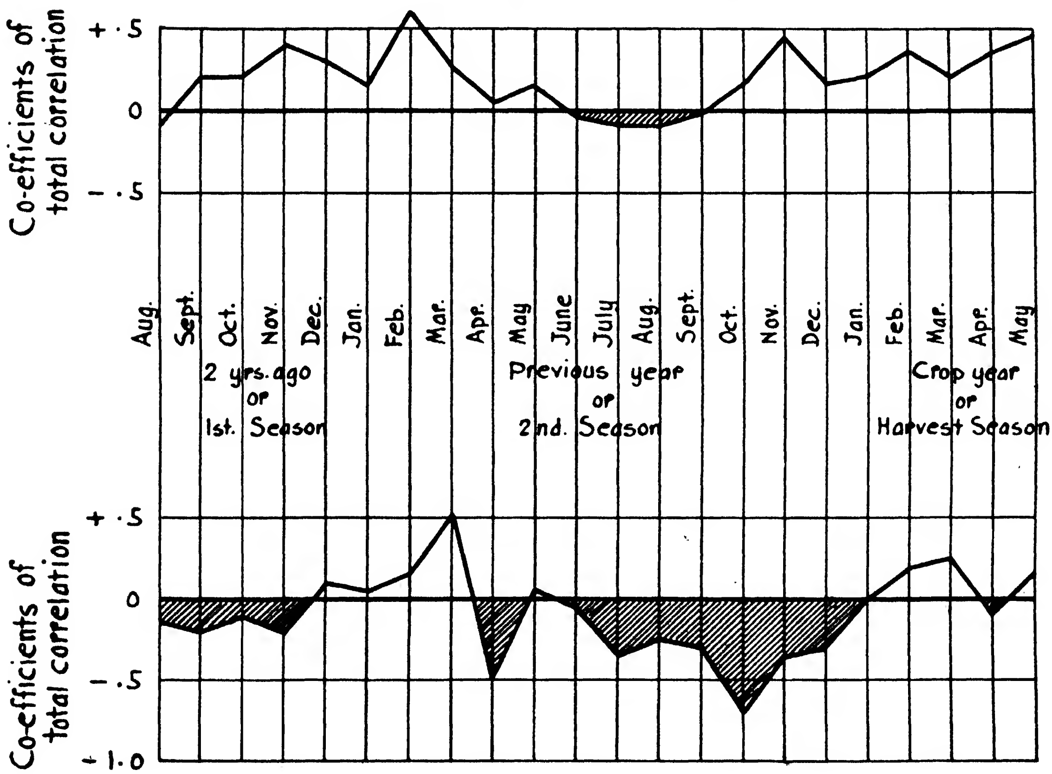


Fig. 7

Ewa Plantation Co.

Co-efficients of Correlation between Purity of Crusher Juice and (A) Mean monthly maximum temperature (B) Mean monthly minimum temperature

(A) Purity and maximum temperature

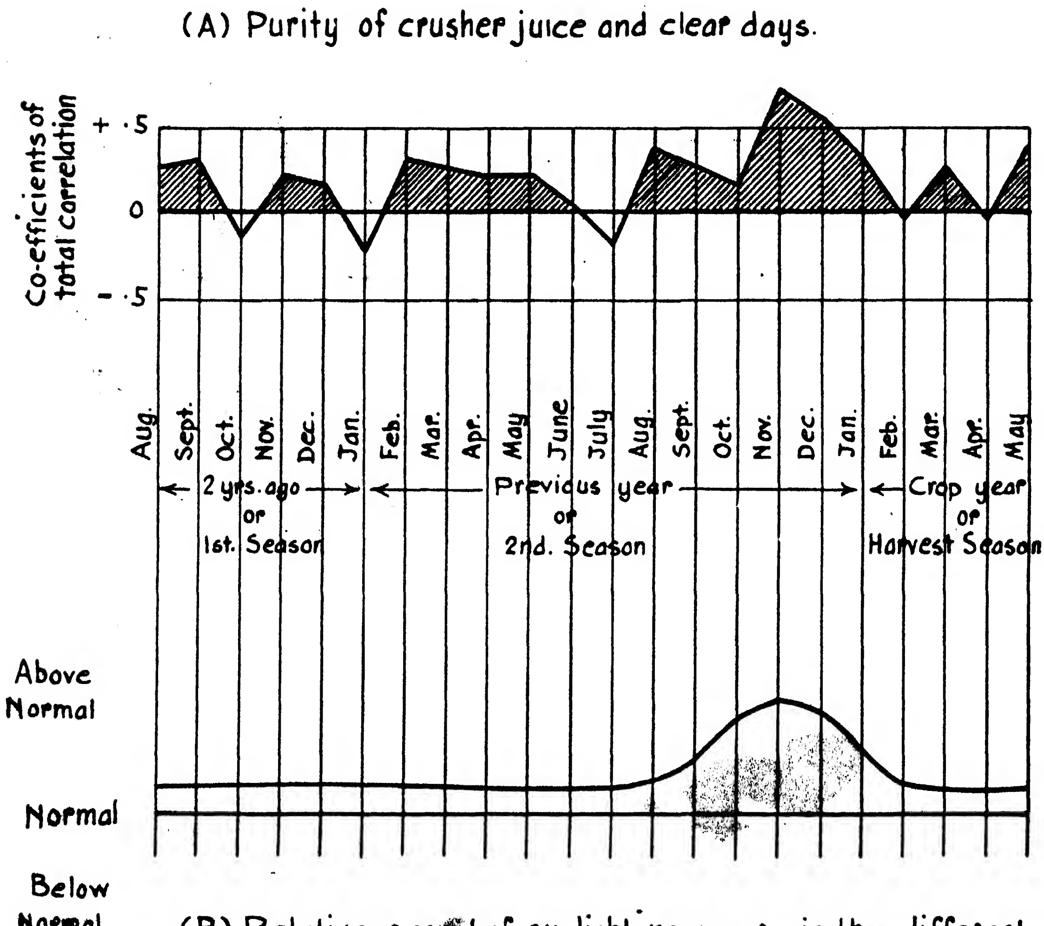


(B) Purity and minimum temperature

Fig. 8

Ewa Plantation Co.

Co-efficients of Correlation between Purity of Crusher Juice and Number of Clear Days in a Month



(B) Relative amount of sunlight necessary in the different seasons for optimum conditions - a simplified presentation of the upper curve.

Fig. 9

Ewa Plantation Co.
Relationship between the Purity of Crusher Juice this Season and the Number of Clear Days in Nov. of the Previous Year.

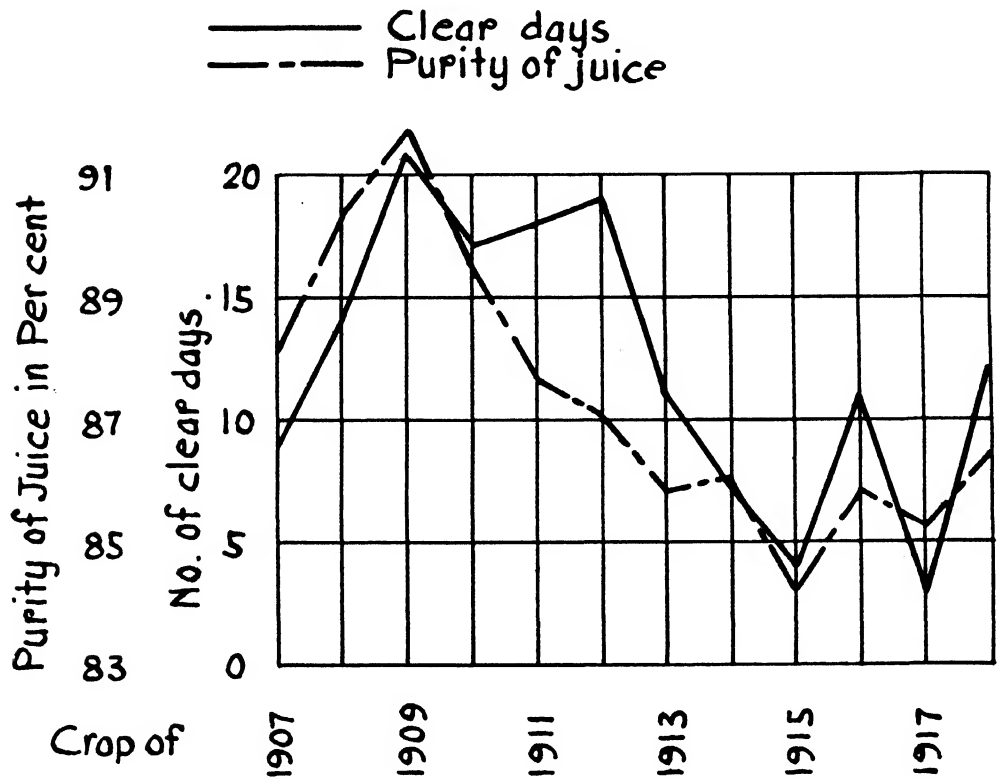


Fig. 10

Ewa Plantation Co.
Relationship between the Purity of Crusher Juice this Season and the Number of Clear Days in the Previous Year

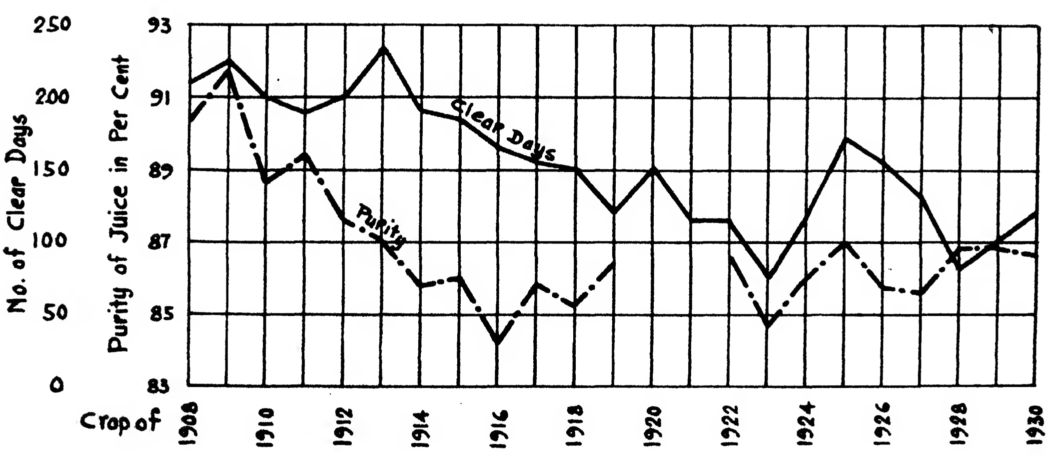


Fig. 11

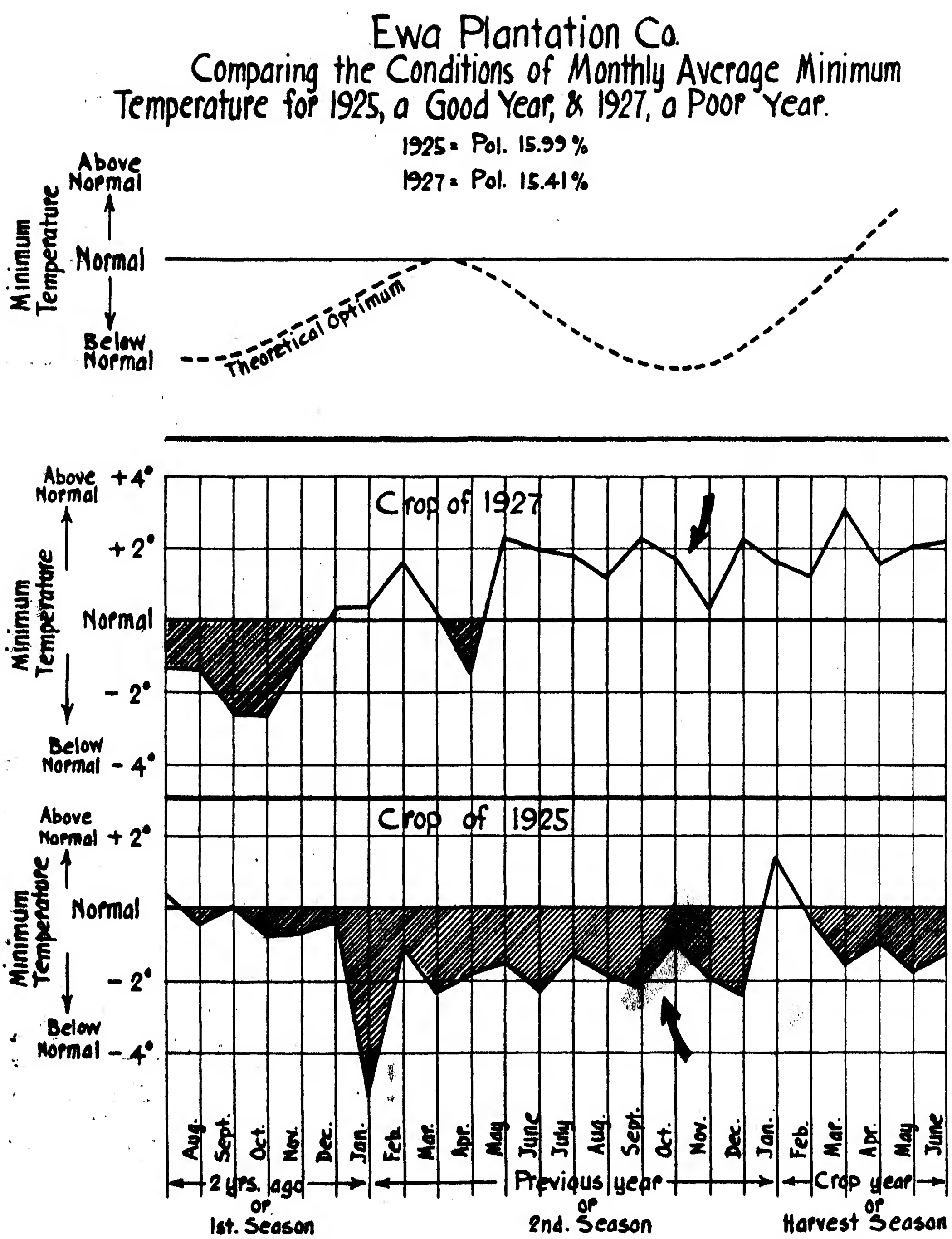

Ewa Plantation Co.
Comparing the Conditions of Monthly Average Minimum Temperature for 1925, a Good Year, & 1927, a Poor Year.
1925 = Pol. 15.99%
1927 = Pol. 15.41%
Minimum Temperature
Above Normal
Normal
Below Normal
Theoretical optimum
Crop of 1927
+4°
+2°
-2°
-4°
Crop of 1925
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
2 yrs. ago or 1st. Season
Previous year or 2nd. Season
Crop year or Harvest Season

Fig. 12

Ewa Plantation Co.
Number of Clear Days During the Growth Period of the Crop of 1925 Compared to that of the Crop of 1927.

1925 = Purity 86.95 %
1927 = Purity 85.57 %

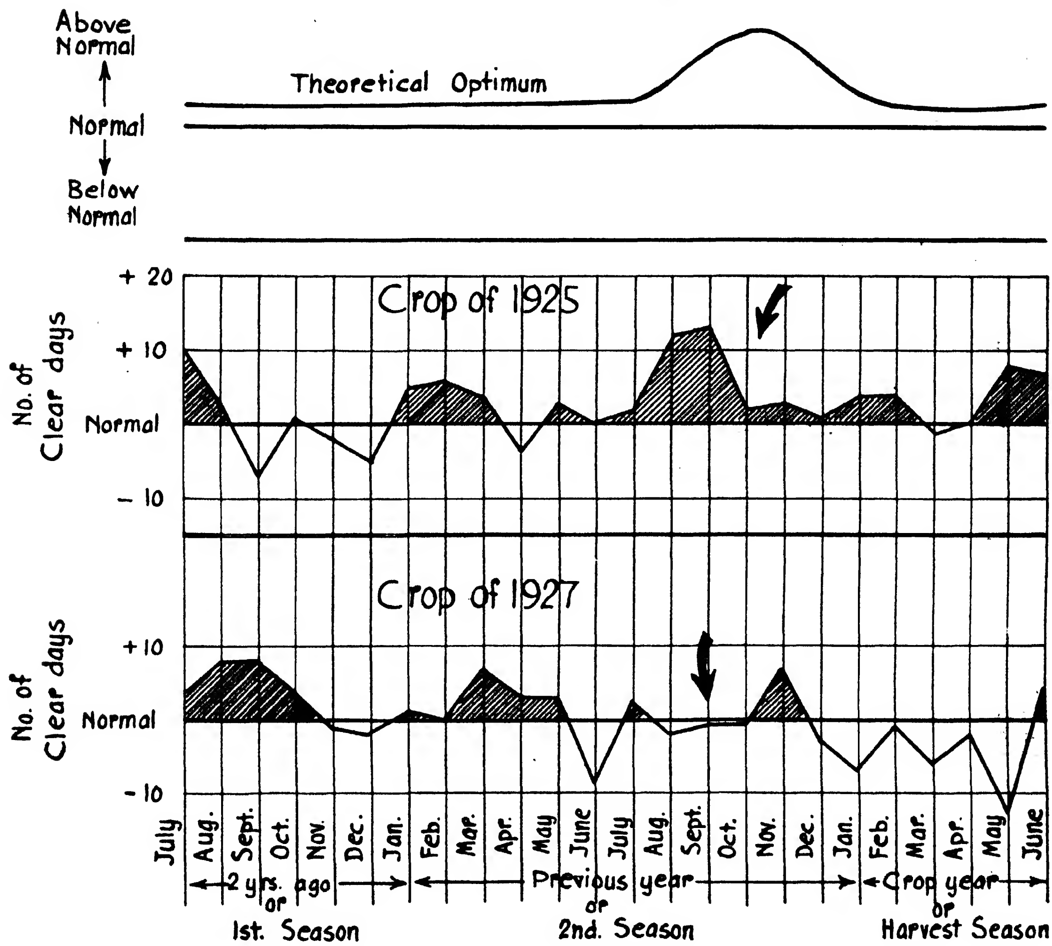
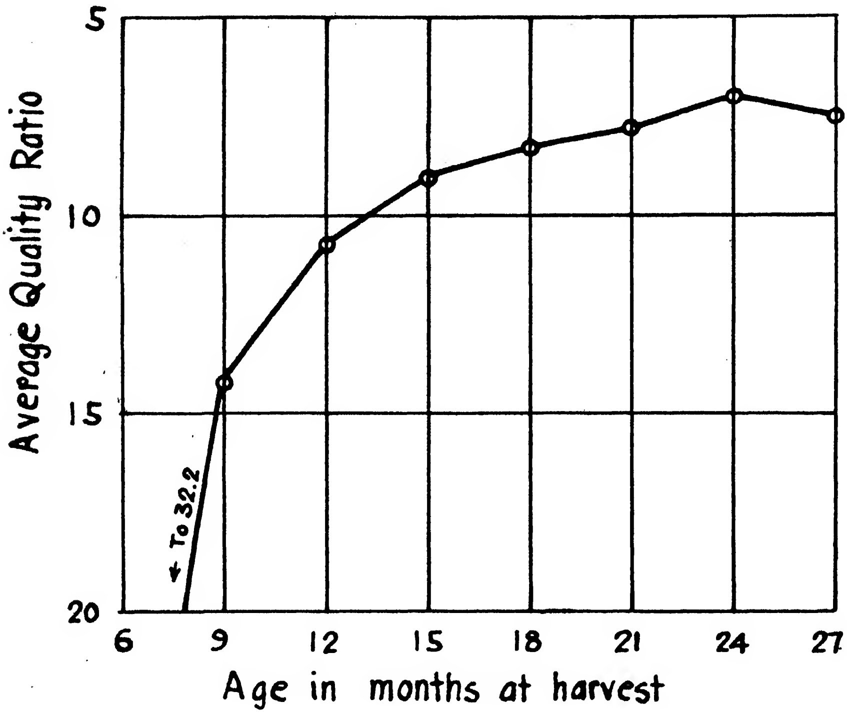


Fig. 13

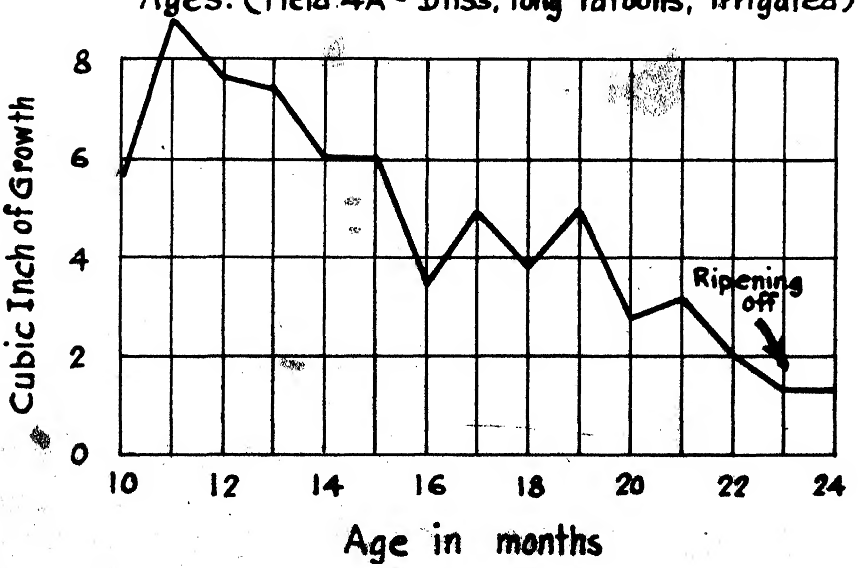
(A) Waipio Expt. E

Average Quality Ratio of H109, Plant, Harvested at Various Ages - Average of Crops Started in Different Seasons.



(B) Paauhau Sugar Co. - Growth Expt.

Volumetric Rate of Growth of Cane of Various Ages. (Field 4A - D1135, long ratoons, irrigated)



The Problem of Juice Quality

By U. K. Das

Foreword

At this time of the year, our inquiries turn naturally to the problem of juices. For almost two years, the crop has been growing in the field. We have given it all the care and attention that we were capable of; the stand of cane in the field had raised hopes of an excellent yield, but now that the field is harvested, we find cause for disappointment. Owing to the poor quality of juice, the yield of sugar is not as high as we had hoped it might be.

We feel sure that the quality of juice is not just a matter of chance but that it is the effect of certain definite causes.

Introduction

Twenty years ago the Territory produced about 37 tons of cane per acre and obtained therefrom about 4.70 tons of sugar. In 1930, we obtained from the same fields an average of 59 tons of cane per acre and about 6.80 tons of sugar. In twenty years we have raised our cane yield 60 per cent, but our sugar yield only 45 per cent. Obviously we have not been getting as good a quality of cane in recent years as we used to. Fig. 1 shows that this deterioration of the quality of juice is not an accident of the last year but that it has been progressing steadily during the last twenty years. As our cane yield has been increasing our juice quality has been going down. The question of juices becomes a matter of the greatest concern when we realize that could we have maintained the quality of our cane, the Territory would have produced about 1,007.500 tons of sugar last year.

Why has the juice been deteriorating? Is it because of soil, climate, because of something we do now that we did not do before? These questions can be answered only when we know how sucrose is accumulated in cane and the factors that influence this process.

The following pages bring together in an outline form information from various sources on the subject of sucrose formation in cane.

The Sugar Cane and Its Environment

We may think of the sugar cane plant as a manufactory where the leaves are the machinery with which sugar is made, the cells of the stalk as the storehouse in which sugar is stored, carbon dioxide, moisture and plant food as the raw materials. Then the total output of sugar will depend on the amount and quality

of raw material, the capacity and efficiency of the manufacturing units and the capacity of the storehouses. But subordinating these three conditions, there are two others, namely (a) the element of time—no matter how efficient the machinery is, only a certain amount of material can be made into finished goods in a given time; and (b) the environmental conditions. As this manufactory is situated out in the open, it is subject to all the vicissitudes of weather, which regulate the efficiency of the machinery, the amount and quality of raw materials and even the number of working hours.

The Sugar Cane Plant—General Considerations

In a very young cane there is very little sugar of any kind. As the cane grows sugars begin to accumulate; at first there is more glucose than sucrose, but as the cane reaches maturity sucrose predominates so that a ripe cane contains only a very small proportion of glucose. (Incidentally this phenomenon finds a practical application in the determination of the ripeness of a cane.) The process of sucrose accumulation, is therefore, intimately related to the process of growth. Hence, we would be quite safe in stating that whatever affects the processes of growth also affects the process of sucrose formation in cane. Observations indicate that the more rapid the growth of cane, the less rapid the formation of sucrose and *vice versa*. But there is no evidence to show that there is a cause and effect relationship between the two. It would perhaps be more correct to say that factors that inhibit rapid growth, promote ripening.

Sucrose is elaborated by the cane leaves and stored in the parenchyma cells of the nodes and internodes.

The following figures from Geerligs (1) (p. 94) show that the internodes contain more sugar than the nodes, because the internodes have a larger proportion of parenchyma cells. Other things being equal, canes having more internodal space are likely to have higher sucrose content than canes with more nodal space.

		Sucrose Per Cent Cane
1	Fibrovascular bundles	15.63
	Parenchyma cells	18.88
2	Nodes	15.5
	Internodes	17.5

If a well-developed cane is cut into three segments, top, middle and bottom, it will be found that the bottom part contains the most sucrose. As the cane advances to maturity this zone of the highest sucrose content moves upwards and in an over-ripe cane it may be located more towards the middle.

Venkatraman and Row (2) (India) give the following figures:

Joints	Polariscope Reading	Approximate Polarization*
Basal 3 joints	— 33.6	8.2
Next 3 joints	— 50.0	12.3
Next 3 joints	— 63.2	15.3
Next 3 joints	— 75.8	18.4
Next 3 joints	— 86 2	20.5
Next 3 joints	— 87.6	20.8
Four joints above dead leaf	— 71.4	17.2

*The polarization figures are supplied by this writer.

Every joint of a sugar cane carries a leaf; the question, then, arises: Can there be any increase in the sucrose content of a joint after the leaf attached to it has died? The work of Kuyper (3) in Java proves that the process of sucrose accumulation does not necessarily stop with the drying out or dying of a leaf. In most of these experiments the sucrose content of a joint went on increasing steadily even after the leaf attached to it had fallen off. (See Fig. 2.) Geerligs (1) (Java) writes:

> At last the joint has reached the period in which the leaf to which it belongs has ceased to assimilate and is dying off. Now the quantity of sugars in the joint increases by the portion which flows to it from the higher parts of the cane and thus is not fixed by the higher joints. As the distance of the joint from the assimilating leaves becomes larger, owing to the death of more and more leaves, the increase in the sugar content grows less until finally we reach the point where the influx of sugar into the joint is totally stopped, but owing to assimilation by the chlorophyll of the rind, the joint gains a little sucrose; however, this profit is more than counterbalanced by the loss of reducing sugar by respiration.

As the parenchyma cells serve as storehouses for sucrose, the manner in which these cells are formed is of the highest importance. Geerligs (1) (p. 85) says:

> If the circumstances of growth and development have been very favorable, the storage accommodation for sugar in the cane stalk is very spaciously built; a great deal of sugar may, therefore, be accumulated in the cells, without the liquid in the cell becoming as concentrated a solution as is the case in cane grown under less favorable conditions where less parenchyma cells are present.

Quintus (4) (Java) says:

> We have seen that sugar formation takes place in the leaves while the parenchyma cells of the stem serve as depositories for saccharose. It is of great importance how these cells, in which sugar is eventually stored, are formed. The cells should be able to form and develop undisturbed, which can only be the case when growth proceeds regularly.
>
> Hence the sugar percentage depends not only on the progress of the monsoon, as we saw before, but also on the manner in which the tissue has been formed, thus also on the manner in which the plant has grown.
>
> The more regularly and normally growth has proceeded, the greater will be the accumulation of sugar.

Location

The location of a place determines to a great extent how a cane variety will grow and ripen under the particular climatic conditions. The seasonal differences in temperature, hours of daylight, length of the growing season, all reflect on the sucrose content of cane. Continental or insular climate have also a bearing on juices. An insular climate will have less range of temperature between day and night and between seasons than a continental climate.

Likewise, elevation has a great influence on sucrose content. Other things being equal at higher elevations cane grows slowly but possesses a high percentage of sugar.

Quintus (4) (p. 7) says:

> Besides rainfall elevation above sea level affects the formation of saccharose. In a cool climate more sugar is formed because the cane grows slowly. On estates situated at a high elevation, less cane is always produced, which disadvantage is partly or wholly made up by a greater sugar per cent.

Geerligs (1) (p. 85) says:

On plantations situated considerably above sea level the low night temperatures stop the growth and promote ripening.

Herewith is presented a climatic map of these Islands. (Fig. 3.) A study of this map would bring out that the plantations having poor juices like Kaeleku Sugar Company and Waimanalo Sugar Company are windward plantations having a low daily range of temperature. On the same map, as we move towards the left, the differences between the day and night temperatures increase and we encounter the plantations that usually obtain good juices. It will, further, be observed that the plantations having a high range of temperature are our leeward plantations. These plantations have not only this advantage of favorable temperature conditions but they are also favored in the matter of sunshine.

The reason for the differences in the average quality of juice of our plantations may, therefore, be largely attributed to their location.

Variety of Cane

Some canes have normally a high sucrose content. This may be due to some morphological characteristics of the variety, or due to the size, color, texture, efficiency, etc., of the assimilating leaf surface or the storage cells. There is a popular belief in some parts of the world that a yellow to orange colored cane gives a higher sucrose content than cane of any other color. There is no experimental evidence to support this belief. It would, however, be worth while to know if the color, size, etc., of the leaf has anything to do with the sucrose content of a cane.

Some varieties mature early, that is, they will reach maximum sucrose content early in the harvesting season, while those that mature late, will reach it later in the season. This may be due to the inherited qualities of the cane or its feeding habits.

Climate

Of all the factors influencing the sucrose content of a variety, climate is probably the most important. Sunshine, temperature, rainfall, humidity, wind, all of these vitally affect the growth processes of the cane plant. In spite of our best efforts, the sucrose content of our cane varies from year to year due more to weather conditions than to any other single factor. If we study Fig. 4 we will see that the fluctuations in the average quality ratio of the four islands of the Territory are very similar from year to year—this in spite of soil variations and different varieties of cane. Sir A. D. Hall (5), former head of the Rothamsted Experiment Station, says:

Even on the Rothamsted plots, where the differences in the supply of nutrients are extreme and have been accumulating for fifty years, the composition of the grain changes more from one season to another than it does in passing from plot to plot.

I. A. Colon (6) (Porto Rico) writes:

The last experiments of the Insular Experiment Station seem to indicate that climatic conditions have greater effects on the purity of the juices than the fertilizers applied.

Sunshine

Carbohydrates can be manufactured only in the presence of light. Light controls the chemical reactions of the leaf because it is essential *per se* and also because sunshine modifies the temperature of the air and the plant cells. No doubt the name "crystallized sunshine" as applied to sugar arose from observations that places with plenty of sunshine usually give canes of high sucrose content. Noel Deerr (7) (p. 27) says:

> A factor that has influence on the composition of the cane is that of direct sunshine as bearing on the process of change known as photosynthesis. This factor may reasonably be of some moment in the wetter districts and may account for the low percentage of sugar in canes grown in the equatorial rain belt.

Our studies (8) indicate that the amount of sunshine is of importance even in our dry, irrigated plantations. Fig. 5 shows that the purity of juice at Ewa from 1903-1917 bears a close relationship to the total number of clear days in the years 1902-1916, respectively.

The duration, intensity and also the quality of sunshine have influence on sucrose content.

Temperature

The great influence of temperature on the sucrose content of cane has always been recognized. Thus Geerligs (1) (p. 83) writes:

> In subtropical countries temperature has a very marked influence on the sucrose content of the cane. This has been shown for Louisiana by Browne and Blouin, in the results of years 1903 and 1904, which were very dissimilar as regards weather conditions.

	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Nov. 15
			1903		
Sucrose	2.70	5.97	11.27	13.60	15.86
Reduced sugar	3.80	3.68	2.51	1.02	0.63
Purity	36.00	57.02	76.72	87.85	92.10
			1904		
Sucrose	2.35	5.13	8.04	9.13	12.00
Reduced sugar	4.04	3.75	3.55	2.82	1.66
Purity	32.28	52.35	66.61	71.55	80.53

> The weather of the two years was as follows:

		July	Aug.	Sept.	Oct.	Nov.	Dec.
Average daily temperature	—1903	82.80	82.10	77.0	67.90	58.00	49.00
	1904	80.90	84.10	84.20	71.20	64.30	58 40
Rainfall, inches	—1903	5.55	5.98	1.27	0.36	0.23	3.89
	1904	6.47	5.75	3.24	0.75	1.50	3 02

Ishida and Sawasaki (9) (Formosa) find:

> The coefficient of maturity is mainly influenced by atmospheric temperature during the maturing season so long as the season is dry. The relationship is inverse.

The same writers find that for each degree (centigrade) rise in temperature above normal during the ripening season, Rose Bamboo decreases in sucrose con-

tent by 0.478 per cent and for each degree fall in temperature below normal, the sucrose content increases by 0.946 per cent. Noel Deerr (7) (p. 25) writes:

> The temperature range has a very important bearing on the composition of the cane. In those places that have a uniformly high temperature and no cool season, an impure cane of low sugar content and high in reducing sugars is almost invariably harvested. In such a case there is opportunity for continuous vegetative growth and the crop as it reaches the mill will consist of canes in full vegetative vigor, of ripe and of over-ripe canes. In extra-tropical climates, as in Louisiana, the limited period of growth affords a cane that does not have an opportunity to reach maturity.

Koenig (10) (Mauritius) finds that the sucrose content of cane is inversely related to mean air temperature of the ripening season and in his opinion:

> The calculation of the probable sucrose content of cane at least for typical localities of the colony could be performed with sufficient accuracy for practical purposes if more extended series of temperature observations and especially of observations of the moisture content of the soil were available.

McDonald (11) (Louisiana) found that low temperature in the fall months prior to harvest tended to slightly improve the sucrose content of cane. But during the actual harvesting period warm conditions were essential. Most of the writers referred to mention the influence of temperature just prior to harvest, but our studies (8), (12), indicate that temperature conditions during the entire growth period of a crop are of moment to the sucrose content of cane. A statistical study (8) of the juices of the Ewa Plantation Company brings out that for high sucrose content the days should be warmer than normal during the entire life of a crop except in the second season summer and the late fall and early winter months of the harvesting season. The nights, on the other hand, should always be cooler than normal. These studies also point out that temperature conditions during the grinding season are of less moment than during the fall months prior to harvest.

Therefore, for ideal conditions we should have warm days and cool nights.

Van Deventer (13) (Java) observes:

> The rendement of cane grown a few hundred meters above sea level is, as a rule, higher than the one of cane grown in the lowlands. It is assumed that the low night temperatures which prevail in the higher altitudes aid the ripening of the cane more than any other single factor.

In the climate map of these islands, referred to previously, it will be seen that our poor-juice plantations have generally the smallest differences between day and night temperatures.

The complex processes involved in a ripening cane are still little understood but the following considerations may partly account for the distinct influences of day and night temperatures on the sucrose content of cane.

Temperature during the daytime controls the processes of assimilation, translocation and respiration of the plant. During the nighttime, the process of assimilation by which the leaf elaborates carbohydrates stops, but the other two processes still go on. The process of respiration causes a loss of material elaborated during the daytime; for some of the material is broken down to supply the energy for

the chemical reactions in the plant. Within certain limits, the higher the temperature the greater the respiratory activity of the plant. Now, if we consider the total matter stored in the plant as the difference between total matter assimilated and total matter lost by respiration (net gain equals amount assimilated minus amount lost by respiration) then, we can see that relatively high night temperatures will produce a greater loss of elaborated material and thus prevent the accumulation of a large amount of sucrose in the plant.

Blackman (14) quotes the following results of an experiment of Lundegardh's:

ASSIMILATION AND RESPIRATION PER HECTARE OF A POTATO FIELD

Assimilation	Respiration	Gain	Per Cent Gain
300 kilograms	175 (20° C.)	125 K. G.	100
300 kilograms	132 (10° C.)	168 K. G.	130

Thus a difference of 10° C. in temperature at night made a difference of 30 per cent in the total weight of matter gained.

Rainfall

In unirrigated places, rainfall is one of the most important factors influencing the sucrose content of cane. The total amount as well as its distribution are of importance.

Quintus (4) (p. 4) writes:

> Sugar cane requires a fairly accentuated alternation of monsoons. It is necessary that a period of plentiful rain be succeeded by some months of dry weather, as otherwise the cane is unable to attain full maturity, so that a large crop of cane is indeed gathered, but the percentage of sugar is so small that the profit is inconsiderable, especially when selling prices are low. Likewise, the time when the dry period commences is of importance; if it arrives too late, the cane does not ripen completely; and this is also the case if the dry weather sets in too early; when the cane, moreover, dies prematurely.
>
> As a rule some few rain showers at harvest time have no influence or cause only an apparent diminution of the sugar percentage, as the juice is diluted by the absorption of water without affecting the total amount of sugar.

Geerligs (1) (p. 84) says:

> In tropical countries where the average temperature does not vary much in different years, the sucrose content of the cane is not so much influenced by the temperature as by the rainfall. Kobus (*Proceedings of the Eighth Sugar Congress*, Soerabaya 1907, 40) illustrated this in the table below:

	Sugar Extracted from 100 Cane	May-October Ripening Time: Avg. Monthly Rainfall	May-October Ripening Time: Inches per 1000 of Year's Total	Oct., Nov., Dec. Soon After Planting: Rainfall in 3 Months	Oct., Nov., Dec. Soon After Planting: Inches per 1000 of Year's Total
1894	10.36	2.16	127	23.62	368
1895	9.79	4.66	249	18.74	340
1896	10.55	0.74	51	17.60	310
1897	10.06	1.38	87	19.37	339
1898	10 21	3.46	185	27.95	417
1899	10.94	2.28	160	18.23	326
1900	9.57	4.56	263	17.72	288
1901	10.16	3.42	176	19.10	310
1902	10.77	1.10	67	11.85	96
1903	10.03	2.48	131	25.78	418
1904	10.74	3 07	174	20.59	347
1905	10.37	2.12	129	13.27	233
1906	10.04	3.11	184	26.61	396

Van Deventer (13) (Java) writes:

The earlier the west monsoon rains begin (at start of crop) the higher becomes the rendement and sugar yield; the yield of cane on the other hand is less influenced by this factor. If the rains are late in starting and the east monsoon (dry period) has been long, the effect is a low rendement and low sugar yield.

Drought not only lowers the cane yield but also the sucrose content. Geerligs (1) (p. 85) says:

Cane having had an abnormal growth owing to drought often ripens very rapidly; the ripening process proves to be very short, the cane soon becomes over ripe and loses in sugar content.

Our study (12) of the quality of juice at the Pepeekeo Sugar Company supports the statements just referred to. Fig. 6 shows that at Pepeekeo Sugar Company high sucrose content in cane is associated with plentiful rainfall during the growing season and dry weather for a few months immediately preceding and during harvest time.

Thieme (15) (Java) shows that if the weather is too dry during the growing season, then this will result in a cane of low purity at harvest.

The belief that a dry harvesting period is essential to high sucrose content is so firmly implanted in the minds of many that it is necessary to mention that this is not the case everywhere.

Geerligs (1) (p. 86) says:

A dry harvesting time is favorable for the ripening on an estate having moist low lying land, but unfavorable for estates on a loamy, easily-cracking soil, where the rootlets may be torn asunder, if the cane is not cut before the land has dried up.

Van Deventer (13) (p. 1) says:

For good maturity of the cane, a dry period is very desirable, but under no condition should this period start before the growth is nearly completed. If this is not the case, then the cane does not mature, but begins to die while still immature.

Other Climatic Factors

Somers-Taylor (16) (India) showed that the early and late ripening of the same variety of cane in succeeding years was correlated with the humidity of the air in the months preceding harvest. Low humidity in those months induced early ripening.

The question will naturally arise: Which has the more influence on the sucrose content of cane—sunshine, temperature or rainfall? All are of importance. In localities where rainfall is the more variable element from year to year sucrose content of cane will fluctuate more in accordance with rainfall variations but where rainfall is of no great consequence as in the case of our irrigated plantations, variations in temperature will surely reflect more on the composition of juice from year to year. The same consideration holds true in the case of sunshine. In other words, sucrose content will fluctuate with any of these principal factors that happen to be limiting at the time.

Soil

Both the physical and chemical composition of the soil affect the composition of the juice. In a porous or well-drained soil cane matures early, because the soil dries out quickly; on the other hand, a soil with a high water table or poor drainage loses moisture very slowly, vegetative growth can proceed for a longer time and as a result cane ripens very slowly and in extreme cases may never ripen fully.

Geerligs (1) (p. 85) says:

> Cane ripens slowly in a moist soil where it may continue its growth during a long period; on soils which are drying up in a dry season it will ripen much more quickly.

On a soil abundantly supplied with plant food, especially nitrogen sugar cane makes rank growth, may never stop growing and as a result cane of low sucrose content is sure to be harvested; such is often the case in virgin lands.

Noel Deerr (7) (p. 92) writes:

> Lime is credited with producing a sweet and pure juice in the West Indian adage: "The more lime in the field the less in the factory."
>
> Phosphates are also believed to affect beneficially the sugar content of the cane and potash is reputed to have the reverse effect.

Bonazzi (17) (Cuba) says:

> It is found that where cane is grown on limestone soil it had impurities which did not tend to the high production of molasses. Canes grown on soils of a siliceous origin, on the other hand, yielded high melassigenic juices.

The presence of a large percentage of common salt in the soil lowers the sucrose content and purity of juice.

Besides these important minerals in the soil, the presence in small amounts of such elements as boron, manganese, iron, aluminum, etc., may affect the juices by influencing the growth processes of the cane. Some of these like aluminum are definitely toxic to sugar cane; others may be found which are helpful. Experimental evidences on this point are, however, meager.

Agricultural Practices

We have seen that the sucrose content of cane depends on the locality, the climatic conditions and the type of soil. But the effect of any or all of these can be modified by agriculture. It behooves us, therefore, to know the effect of our agricultural practices on the sucrose content of cane.

Time of Starting:

Time of starting has a great influence on the sucrose content. Thus Booberg (18) (Java) writes:

> It appears that the highest rendement is found in areas that were planted in June and harvested in July, thus at an age of about 13 months. The harvesting time seems to have exerted a much smaller influence upon the formation of rendement than the planting date.

Fig. 7 gives the quality of juice of plants and long ratoons at Ewa Plantation Company started at different months of the year. Indications are that the ratoons started in the middle of the warm growing conditions of the summer months give the best juices.

Time of Harvesting:

That the season of harvest has a great influence on the quality of juice is well recognized in these islands. The experience of Java is somewhat different.

Booberg (18) (Java) says:

> Rendement did not vary considerably during the different harvesting months, very early harvesting was surely deleterious.

That there is a definite season during which cane tends to ripen, regardless of variety, age or location, is indicated by Fig. 8, which shows the average month by month quality of juice for the past 22 years. It will be observed that juice quality reaches a peak in May and June.

This is probably due to the seasonal changes in temperature and sunshine. The cool winter slows down growth and sets in ripening. This ripening process receives a stimulus with the advent of the dry season after March with its plentiful sunshine.

After the peak has been passed in May and June, the cane probably begins to deteriorate or new growth starts, both of which result in a loss of sucrose.

However, there are evidences to show that the cultural practices can modify this "season of optimum juice quality". We all know that short ratoons harvested as late as August and September give excellent juices. A study of Fig. 9 (*a* to *d*) will show that in the years 1908-1914, the best month to harvest cane was in April; in 1915-1920 it was in May and in recent years it is in June. This would lead us to conclude that most likely our field practices of today have deferred the maturity of cane by a month or two.

It is the opinion of this writer that by suitable cultural practices we may be able to lengthen this season of optimum harvest—particularly in the irrigated plantations where water is under control. In other words, this peak of the season need not be just one or two months long, it can very likely be increased to three or four months.

Plant vs. Ratoon:

Geerligs (1) (p. 88) says:

> Ratoons generally have a better sucrose content than plants.

In countries like India ratoons are known to be richer in sucrose than plant cane. In Hawaii, on the other hand, plant cane appears to give better juices on the average than long ratoons.

This anomaly may be due to the fact that in Hawaii plant cane is favored in the sense that it is started and harvested at the optimum season and also it receives more care than the long ratoons.

In countries like northern India where the growing season is short, a ratoon

will have an advantage over plant cane, because it starts accumulating sucrose earlier than the plant cane and therefore can show more of it at harvest.

Age of Cane:

As has been said previously, no matter how efficient the machinery is only a certain amount of raw materials can be made into finished goods in a given time. Age of cane at harvest has, therefore, a great influence on the quality of juice. This point is brought out very conclusively in Fig. 10. The chart gains added significance from the fact that the figures for the quality of juice were obtained from cane planted in four different seasons of the year. It will also be seen from this chart that there is such a thing as a cane getting too old and juices deteriorating.

Suckering and Juice:

In a typical field of H 109 in our irrigated plantations there are 2 to 3 suckers to every original shoot. The amount and the manner of suckering, therefore, exercise a very great influence on the sucrose content of cane. If all the original shoots and suckers were ripe at the time of harvest, we would surely get good juices. But this is seldom the case, when the original shoots are ripe, the suckers may still be young and unripe. When the suckers reach maturity, the original shoots may have become too old.

In general, best juices are obtained where the suckers come out early and reach a considerable degree of maturity at the time of harvest.

Rodrigues (19) (Louisiana) found that early suckering was positively correlated with high sucrose content of cane.

Stubbs (20) (Louisiana) writes:

> With few exceptions, there has been a gradual diminution of sugar and of stalk from the original plants to the youngest suckers. This fact emphasizes the necessity of getting suckers as early as possible and after that cultivating to repress them.

Van Deventer (13) (p. 132) writes:

> If they (suckers) sprout late, then they are not ripe at the time of harvest and have very bad juices.

Width of Cane Rows:

Width of cane rows may have influence on juices, because wider rows give more access to sunlight and encourage suckering. However, the evidence so far seems to indicate that under field conditions, width of rows have little or no influence on the sucrose content.

Stubbs (20) (p. 91) writes:

> Experiments indicate that sucrose and glucose are fairly constant for shoots planted 6", 12" and 18" apart in 5 ft. rows.

The same writer says in another place (p. 103):

> In general the narrower the row the larger the yield of cane without injury to the sugar content or its purity.

Locsin (21) (Philippines) found very little difference in the quality of juice of canes planted in rows 3, 4 and 5 feet apart.

Rosenfeld (22) (Tucuman), on the other hand, finds that in Tucuman, Louisiana Purple gave better juices when planted in widely separated rows. These are his figures:

AVERAGE OF PLANT AND LONG RATOONS—PURPLE CANE
(Tucuman Experiment Station)

Width of Rows	Sucrose	Purity
5 ft.	10.7	76.4
6 ft.	12.2	80.3
7 ft.	12.2	82.4
8 ft.	13.3	84.2

Cross (23) (Tucuman) cites the results of recent experiments with P. O. J. 36 and P. O. J. 213. His results indicate that rows about 5 feet wide give the best juices. Increasing or decreasing the width is attended with loss of sucrose.

In this connection it should be remembered that width of rows can influence the sucrose content of cane only in the sense that it determines to a great extent the manner and the amount of suckering and accessibility of sunlight. In narrower rows the late suckers die in the struggle for existence, so that the crop consists of original shoots and early suckers. What handicap narrow rows offer in the matter of sunlight is counterbalanced by the greater age and maturity of the stalks. In wide rows, on the other hand, suckering proceeds late in the season, and consequently a considerable percentage of the suckers are young at the time of harvest. The advantages of more sunlight in the rows is offset by the immaturity of the cane. Most likely, this is the reason why width of rows appears to have so little influence on sucrose content.

Arrowing in Cane:

Observations in all parts of the world point to the conclusion that generally speaking arrowing itself does not lower the juice, if the cane is harvested at the right time. Observations in Java, however, indicate that in some varieties there may be some loss of sucrose due to flowering.

Of the variety Black Java, Geerligs (1) (pp. 71-73) says:

> Arrowing does not, however, affect the composition of the cane to any extent, as may be seen from the analyses.

VARIETY—BLACK JAVA

	*1		2		3	
	Arrowed	Not Arrowed	Arrowed	Not Arrowed	Arrowed	Not Arrowed
Pol of juice	19.3	18.8	19.43	17.93	19.11	19.61
Reduced sugar	0.42	0.44			0.57	0 49
Purity	90.6	92.8	88.3	87.9	90.6	89.14
Fibre on 100 cane	13.2	13.0				

* Numbers indicate different plantations.

Speaking of some P. O. J. varieties, the same writer offers the following:

With other varieties, arrowing appears to have a worse effect, as is shown in the following experiments by Van Vloten (Java Archief, 1896, 636).

	Sucrose	Purity	Glucose	Yield of Sugar Per Cent per 100 Cane
P. O. J. 36 —Arrowed	15.42	88.62	0.40	10.76
Non-arrowed	16.38	89.02	0.29	11 49
P. O. J. 100—Arrowed	20.15	94.60	0.22	15.20
Non-arrowed	20.55	95.14	0.21	15.60
P. O. J. 247—Arrowed	16.80	89.84	0.60	11.92
Non-arrowed	17.60	90.72	0.47	12.64

In Hawaii, Allen (24) reported that tasseled stalks of Yellow Caledonia had less sucrose and purity than non-tasseled stalks. On the other hand, Jennings (25) found that in D 1135 and H 109 the reverse was the case. Naquin (26) wrote of the present status of this question as follows:

The consensus of opinion is that tasseled canes if harvested right after tasseling may give as much, if not more, sucrose than untasseled cane. Delay in harvesting causes deterioration in tasseled cane.

Stripping of Cane:

In the earlier days stripping of cane was advocated as a means of letting more light and air into the cane rows and increasing the sucrose content of cane. All evidences prove that stripping has no influence on the quality of juice. Thus Van Deventer (13) (p. 397) writes:

Stripping has no influence on rendement though it lowers the yield of cane and sugar.

Eckart (27) says:

Juice of unstripped cane is practically the same as the juice of stripped cane.

Hilling-up:

In places where the cane is planted in the bottom of furrows and then hilled up, the time of hilling-up affects the sucrose content of cane. Thus Van Deventer (13) (p. 390) says:

Hilling-up at two months gave slightly better rendement than hilling-up at 3 months.

Fallen Cane:

In Hawaii, very little concern is felt over cane prone on the ground. In fact, with heavy fertilization and two years' growth in the field, very few canes will be able to stand erect; but in other countries fallen canes reflect to the discredit of the farmer. In the sugar cane tracts of India, the clumps of cane are tied together or supported by especially erected barriers to prevent the cane from falling, so great is the fear of losing sugar in the fallen cane. Fallen canes are looked upon with great disfavor in Java. Geerligs (1) (p. 73) writes:

When the cane falls, the sucrose and the quotient of purity decrease considerably. The fallen canes are heavier and longer than the standing ones from the same stools. On the other

hand, their sucrose and fibre contents are inferior, and their water and reducing sugar contents higher. These differences point to unripeness in the fallen canes which grow more rapidly but ripen more slowly.

Van Deventer (13) (p. 470) says:

The greatest disadvantage of recumbency consists in a lowering of the sugar content.

Further experiments in Java show a loss in sucrose and purity in all fallen canes whether the canes were shaded or not.

Fertilizers

Of all the agricultural practices affecting the quality of juice, the application of commercial fertilizer is perhaps the most important. In fact, fertilizers are the only agencies at our easy command through which we gain some mastery over the elements to which the crops are subject.

Nitrogen:

Nitrogen is the most widely used fertilizer for sugar cane. Nitrate of soda and ammonium sulphate are the two most popular, though the use of more concentrated artificial fertilizers like calurea are coming into greater use. Nitrogen is essential for the formation of protoplasm. The application of nitrogen stimulates production of leaves, darkens their color, and promotes the various vegetative activities of the plant. Recent studies by Gregory (28) show that while the application of nitrogen increases the leaf area, it does not increase the efficiency of the leaves as assimilating surfaces.

While nitrogen is a powerful weapon in the hands of the agriculturists, evidences indicate that unwarranted use of this weapon may actually cause harm. While heavy applications of nitrogen increase the yield of cane, they do not always increase the yield of sugar, due to the loss in the quality of juice. This loss is probably due to the fact that nitrogen prolongs vegetative growth and delays maturity. In Hawaii, heavy applications of nitrogen have come into question of late years and have been blamed for lowering the sucrose content of our cane. Fig. 11 is reproduced from the Annual Report of the Experiment Station for 1930, showing the loss in the quality of juice due to increased applications of nitrogen. Alexander (29) finds an average loss of 2 per cent of sucrose for each application of 50 pounds of nitrogen over 150 pounds at Ewa Plantation Company. In the opinion of this writer, nitrogen may not be responsible *per se* for the deterioration of our cane juices. This will be clear from the following considerations:

Physiologists tell us that in the formation of new protein material, such as leaves, tissue, etc., the nitrogenous amino acids brought up by the roots combine with the carbohydrates elaborated by the leaves. Naturally the greater the amount of nitrogen conveyed by the roots, the more will be the requirement of carbohydrate. As a result, comparatively small amounts will be stored by the plant as sugar. By applying a heavy dose of nitrogen we are increasing the storage capacity of the plant but leaving less to be stored. The result is that we are harvesting cane low in sugar.

These considerations appear to suggest that if we could increase the assimilating efficiency of the leaves or if we allowed the sugar cane plant sufficient time to store sugar and mature after it had used up all available nitrogen, we would very likely harvest cane of good juice. In other words, application of nitrogen delays maturity but does not lower the juice on account of any particular quality that it possesses.

Thus Geerligs (1) (p. 85) writes:

Fertilization with nitrogenous manure influences the growth of the cane and therefore likewise its sugar content. This influence does not act in a direct manner but rather in an indirect one, since such fertilization may retard or prolong the vegetative period. If the fertilizer has been applied late or a long acting manure, such as filter press mud or dung has been used, the growth does not cease and ripening will be retarded.

Noel Deerr (7) (p. 50) writes:

There is a widespread belief that heavy manuring adversely affects the quality of the juice of the cane, and under certain conditions this may be correct; thus in a district such as Demerara, where a short period of growth obtains, a late manuring results in an impure juice. Possibly in such a case not only is the maturity of the crop delayed, but a second growth of young cane is stimulated and the comparison may become one of immature and mature cane. Again with heavy manuring there is a consequent increase in the size of the crop with less access of direct sunshine, and a delayed ripening is the result.

On the whole, the writer (Noel Deerr) thinks that the bulk of the evidence points to weight of cane only as being affected; differences which may from time to time be observed are probably due to different degrees of maturity or to other uncontrollable factors vitiating the comparison.

Earle (30) (Porto Rico) writes:

In the literature statements will often be found that while one can increase tonnage by the use of fertilizers, these do not affect sugar content. Other writers caution that fertilized cane will be less rich in sugar than that which is not fertilized. Both of these sets of writers ignore the fact that sugar content is more dependent on ripeness than on any other one factor.

Where fertilizers are applied late, especially the slow-acting organic fertilizers, the tendency is to force growth late in the season, thus preventing early maturity.

Somers-Taylor (31) (India) says:

It may be stated that such a top dressing of manure appears to weaken the juice of the sugar cane at the beginning stages of coming to maturity and delays its actual ripening for about a fortnight but that it is only a delay, and not a prevention of ripening, as in the case examined the treated plots appear to have given juice of almost the same richness as the blank plots. The only difference being that the stage of maximum maturity was reached a fortnight earlier in the case of the plots which did not receive a top dressing.

A study of the fertilizer practices of these islands tends to confirm what seems logical from a theoretical point of view and also what appears to be the consensus of opinion among the leading sugar cane techonologists of the world.

The illuminating Fig. 12 was published by Naquin in 1910, to show that the effect of heavy applications of nitrogen (up to 180 lbs.) was simply to retard maturity. The following excerpt is from Naquin (32):

It may be well to keep in mind that there is every reason to believe that any fertilizing material which will increase the yield of cane will have a proportional depressing action on the quality of cane until such time when other factors set in and mature the cane, at which time no noticeable difference exists between differently treated cane.

Plots receiving 180 pounds nitrogen reached maturity later, at which date all the treated and untreated plots had the same juice.

That under certain conditions large amounts of nitrogen may be applied without adversely affecting the quality of juice, is shown very clearly in a recent experiment at Honomu Sugar Company (Experiment 44, 1931 crop, D 1135, 23 months old, last application of nitrogen 13 months before harvest). The results show that there is not only no loss in sucrose due to an application of 240 pounds nitrogen per acre but that there is actually an increase over an application of 140 pounds of nitrogen.

RESULTS

Pounds Nitrogen	Q. R. (Tons Cane per Ton Sugar)
140	10.21
190	9.14
240	9.25

Fig. 9 (*a* to *d*), referred to previously, appears to support our contention that the increasing applications of nitrogen simultaneously with a decrease in crop length are delaying the maturity of the cane in these islands and the progressive deterioration of juices may be due more to this one factor than any other.

It will be observed in these illustrations that in 1908-1914, canes harvested in April gave the best quality of juice; in 1915-1920, it was in May and in recent years the best juices are being obtained from canes harvested in June. In other words, the optimum maturity of our cane comes two months later now than it did in 1908-1914. Varietal or climatic changes do not account for this delay of two months and we are forced to think that this shift is due to the enormous increase in the amount of fertilizers that are being applied today as compared with 10 or 20 years ago.

That sugar cane is not the only plant to react in this manner to nitrogen will be clear from the following statement of Sir A. D. Hall (5), former head of the Rothamsted Experiment Station in England:

As the amount of available nitrogen is increased the development of leaf and shoot increases, their green color deepens, and maturity becomes more and more deferred, so that a crop grown on land over-rich in nitrogen always tends to be late and badly ripened.

The question then arises: If heavy applications of nitrogen defer maturity, could we get good juices by leaving the cane longer in the field?

Alexander (29) finds that the depressing effect of nitrogen on juices is not offset by longer crop length.

Van Deventer (13) (p. 422) says:

The difference in rendement caused by too heavy or too little fertilization cannot be eliminated by leaving the fields standing for a longer period.

The evidences, therefore, indicate that though theoretically we should expect better juices from a greater crop length, in practice it does not always work that way. This is probably due to two reasons: (a) the season of the year—all canes tend to give better juices at certain seasons of the year, irrespective of crop length or treatments; and (b) canes of varying ages in a crop—if the crop stands too long, then, some cane will have passed maturity and started deteriorating. The profitable crop length from the point of view of juice quality will, therefore, be different in different localities, with different varieties and under different cultural and environmental conditions. The question of crop length in connection with nitrogen application is one that deserves careful and detailed study from our investigators.

There are possibly other ways of offsetting the depressing effects of nitrogen on the quality of juice, such as the time of application or the application of other plant foods together with nitrogen. These points are discussed in another place in this report.

At this point the question may naturally be asked: Does heavy fertilization cause any harm to the anatomy of the sugar cane plant? Do the cells become deteriorated or less efficient? Quintus (4) (p. 84) offers the following answer:

> If growth is artificially accelerated by too much manure or water the consequence is that fewer cells are formed, because cell distension has already set in before division is altogether over; and that the cells overgrow their strength because of which the chances of the tissue becoming spongy are greatly increased. Becoming spongy means death, so that the tissue may be regarded as lost for the storing of sugar.

We do not know of any experimental evidence in support of the above statement.

Phosphoric Acid:

Phosphoric acid is reputed to hasten maturity in grain and cereals. In sugar cane literature there is very little information on the effect of phosphates on juices.

Sanyal (33) (India) writes:

> Superphosphate has the greatest influence in producing a juice with the highest purity and sucrose content.

Cross (34) (Tucuman) thinks that the application of phosphoric acid may induce early maturity in plots heavily fertilized with nitrogen.

Deerr (7) (p. 92) says:

> Phosphates are also believed to affect beneficially the sugar content of cane and potash reputed to have the reverse effect.

Verret (35) thus sums up the local experience:

> Applications of P_2O_5 have no effect on juice quality.

Potash:

Potash is known to be essential to the formation of carbohydrates. As sugar

cane plant is primarily a storehouse for carbohydrates, it would appear that potash applications ought to improve juices.

There is much difference of opinion in the literature on this subject.

Alexander (36) writes:

Potash fertilization has increased cane yields at Ewa Plantation Company. This increase in cane yield was often accompanied by an improvement in sucrose content.

Conant (37) says:

At Olaa there have been instances where potash derived from muriate of potash when applied at the rate of 200 pounds K_2O per acre with the first dressing of fertilizer on Yellow Caledonia not only gave an increase in cane yields over 150 lbs. K_2O per acre but apparently improved the juice quality as well.

This improvement is probably met with only in certain areas for Verret (35) in averaging the results of fertilizer experiments comes to the conclusion that generally speaking applications of potash have no influence on juices.

Other Chemicals:

Liming the soil is known to improve the juices in certain countries like the West Indies; local experience has shown no gain from liming soils.

Traces of certain chemicals in the soils are believed to influence crop growth and quality.

Thus Pestana (38) (Brazil) found that applications of a small amount of manganese together with complete fertilizer gave better sucrose and purity than complete fertilizer alone.

Time and Number of Applications:

Another aspect of fertilization that has a great effect on the quality of juice is the time and number of applications. This question of time not only involves the season of application but also the age or stage of development of the cane at which the fertilizer is applied.

Experiments in Hawaii point to the conclusion that the best juices are generally to be obtained when the fertilizers are applied early and a sufficient interval is allowed between the last application and the time of harvest.

Verret (39) in reviewing experiments on this subject says:

We are very strongly convinced that we can very materially improve our juices and increase our yields of sugar by early intensive fertilization. This means applying all the fertilizer within six months.

The following example bears out this conclusion very forcibly:

PIONEER MILL CO. 1927 CROP—EXPERIMENT 56

[Planters' Record XXXI]

Plots	Fertilization—Lbs. Nitrogen					Total Lbs.	Q. R.
	June, 1925	Sept., 1925	Nov., 1925	Feb., 1926	April, 1926		
O	50	70	120	0	0	240	8.31
N	50	70	...	120	0	240	8.74
Q	50	70	60	0	60	240	8.72
P	50	70	60	0	120	240	8.81

The harmful results of continuing fertilization late in the season is shown by another experiment:

WAIPIO EXPERIMENT 8—1921 CROP

Cane 21 Months Old
[Planters' Record, XXIV, p. 281]
270 Lbs. N Were Applied in 2, 4 and 6 Applications

Plots	Treatment	No. of Plots	Q. R. H 109
A	2 applications	28	8.48
B	4 applications	28	8.75
C	6 applications	28	8.89

Alexander (29) says:

> The key to profitable fertilization is application at the proper time. There is a point in the cane's growth when no further nitrogen or only small amounts can be applied with safety. Great care must be exercised in not giving the cane an overdose in the second season.

The feeding habit of the different varieties should also come in for consideration in deciding the proper time to apply fertilizer.

Kind of Fertilizer:

It is conceivable that the effect of a fertilizing element, nitrogen, phosphoric acid, etc., may vary with the ingredients from which these are derived.

Results of many experiments in Hawaii do not show any difference between nitrate of soda and sulphate of ammonia on the quality of juice.

There is also no evidence as yet that the forms of P_2O_5 and K_2O in present use in Hawaii differ in their effect on juices.

In sugar beets, however, it has been noted that sulphate of potash and muriate of potash give juices of different quality. Schreiber (40) (Belgium) found the following results:

Crop—Beet	Sugar Per Cent
Without potash	12.80
With sulphate of potash	14.20
With muriate of potash	15.30

Availability, Mode of Application, Etc.:

The effect of a fertilizer will depend on its availability and availability in turn may depend on the mode of application.

Fertilizer Balance:

A great deal of interest has recently been shown on the subject of proper balance of fertilizers. Some investigators have claimed that the harmful effects resulting from the use of one single fertilizer element may be corrected by giving adequate amounts of some other elements.

Thus Moir (41) states that the quality ratio is low not with the lowest or the highest nitrogen but with a balance of N, P_2O_5 and K_2O.

Cross (34) (Tucuman) says:

> It is noted that the one-sided fertilization (ammonium sulphate only) results in a low purity cane. It is thought the purity of juice may be improved by the concurrent use of phosphates.

Colon (6) (Porto Rico) writes:

> A heavy application of nitrogen to soils poor in phosphoric acid and potash results in a great foliage development without a corresponding increase in the growth of the cane, so, in order to obtain uniformly good results, the use of well balanced fertilizer mixtures is the best and safest method to follow.

Hach (42) (Porto Rico) thinks that "the real reason why too much nitrogen will reduce the sugar content of cane stalks" is due to lack of enough potash. The author suggests that every time we apply a dose of nitrogen we should apply potash with it and also make sure that there is plenty of available potash in the soil all the time.

Irrigation

Irrigation is one of the most powerful weapons in the hands of the sugar cane planters for the ripening of cane. Like rainfall, it must be well distributed in sufficient amounts to give the best results. In other words, there should be plenty of water when the presence of excellent weather conditions and abundance of plant food promote rapid growth. It should be less and less as the cane approaches maturity. If the cane plant does not have enough water when it is growing fast or has too much when it should be ripening, in either case a low percentage of sucrose will result. From these conditions, it follows that mere drying of the cane before harvest cannot ensure good sucrose content in cane.

Some data obtained from a previous study of the Ewa Plantation Company tend to show that the total amount of irrigation water has a close relationship to the quality ratio. (Fig. 13.)

Van Deventer (13) (pp. 382-383) says:

> Experiments of Kobus and Schult show that sufficiency of water has a very favorable influence on sucrose content.

In another place the same author writes:

> Sugar cane is a crop which needs very much water for its best development. As soon as there is lack of water, the cane is disturbed in its regular growth and stagnation takes place, which causes a lowering of the rendement and of the cane weight. There is also a danger in drying the cane too much by withholding water before harvest. Too much drying may result in raising the Brix only but the quality ratio may not improve due to loss in purity.

Verret (43) and others found that a non-irrigation interval of 40 days before harvest was as good, if not better, than an interval of 60 to 90 days. About the harmful effect of excessive drying, Geerligs (1) says:

> As long as the cells remain alive, the composition of the juice does not appreciably alter,

but as soon as they die the reducing sugars increase at the cost of the sucrose. The chief cause of the death of the cells is the drying up of the cane.

The Salt Content of Irrigation Water Has an Effect on Juices:

Row (44) (India) found that plots irrigated with saline water invariably gave juices of low sucrose content and purity. Blouin (45), Eckart (46) and Maxwell (47) in Hawaii found conclusive proofs of the lowering of the sucrose content of cane from applying irrigation water containing more than 100 grains of salt per gallon. The following are a set of Eckart's figures:

	Quality of Juice		
Salt per Gallon of Water	Brix	Sucrose	Purity
None	20.28	18 90	93.20
200 grs.	16.46	14.40	87.50
200 grs.	16.56	14.50	87.60
200 grs.	15.89	13.80	86.80

Blouin (Hawaii) supplies the following:

Salt per Gallon of Irrigation Water	Sucrose	Purity
50 grs.	18.1	91.5
100 grs.	18.3	91.2
150 grs.	17.0	90.0
200 grs.	16.4	90.4

Miscellaneous Efforts to Induce Ripening:

The inverse relationship between growth and sucrose has always stimulated inquiries as to the feasibility of checking growth artificially and thus promoting maturity.

Eckart (48) in 1913 suggested the cultivation between the furrows of a ripening field as a means of checking growth by pruning the roots. An experiment on the subject yielded negative results.

In another place the same writer (49) advocated the application of phosphate fertilizers in a well-grown field of cane. His contention was that phosphate would check growth and hasten maturity. Experiments failed to confirm this view.

More recently some plantations are applying final molasses in their last irrigation water so as to help the field to ripen. The theory is that the withdrawal of nitrogen due to the bacterial action stimulated by molasses should induce ripening. The result of one experiment reported (50) did not show any gain in sucrose from applying molasses in the irrigation water. This particular phase of the problem is still being investigated and it appears to this writer that there are no physiological reasons why such a practice should not prove helpful.

Ripening is undoubtedly associated with the activity of the enzymes in the plant and theoretically it should be possible to stimulate the activity of the particular enzymes. The scope of such experiments as the one reported could very well be enlarged.

Diseases and Other Injuries

Cane attacked with diseases often shows less sucrose than healthy canes. Most likely, in the diseased canes the efficiency of the cells are impaired or there is an actual loss of stored sugar.

De Verteuil (51) (Trinidad) reports that there is a loss of 0.04 to 8.2 per cent on sucrose content of juice due to mosaic. Results, however, differ in different varieties and also in the kind of crop plant, ratoons, etc.

Geerligs (1) (p. 70) writes:

> Canes attacked by infectious diseases or by insects do not show such a regular distribution of the constituents as sound ones. Attacks of the cane borer cause the sucrose content to fall, while that of reducing sugar remains unchanged; the same effect being brought about by attacks from woodpeckers. Attacks by the top borer do not seem to affect the sucrose content, but the joints attacked may become infected with the pineapple disease or black rot, causing an increase of reducing sugars.

Hazelhoff (52) (Java) says:

> There is a loss of 26 per cent of available sucrose in joints damaged by striped stalk borer (*Diatraca venosata*).

Lee (53) reports the following losses in the quality of juice due to eye spot disease:

	(1) Pol	Purity	(2) Pol	Purity
Healthy cane	18.79	90.4	17.98	90.2
Diseased cane	12.16	75.1	14.53	85.3

Elliott (54) found that in certain districts in these islands the damage due to rats may bring about a considerable loss in the sucrose content of cane.

Summary

Briefly, then, what are the principal factors that influence the sucrose content of cane?

(1) The variety of cane.

H 109 or Badila will, generally speaking, give better juices than Uba or Kassoer.

(2) Weather conditions.

Bright sunny days and cool nights make for high sucrose. Cloudy days and uniform day and night temperature are associated with low sucrose. In wet districts, a dry ripening season is conducive to high sucrose.

(3) The season of harvesting.

In these islands there appears to be a tendency for cane to come to ripeness in April, May and June, regardless of other conditions.

(4) Nitrogen applications.

Heavy applications of nitrogen, especially in the second season appear to lower the quality of juice.

Injury by diseases, insects and rodents, the physical and chemical composition of the soil, irrigation practices, and many other factors, may influence sucrose content to a greater or less degree.. These have been discussed in the body of the report.

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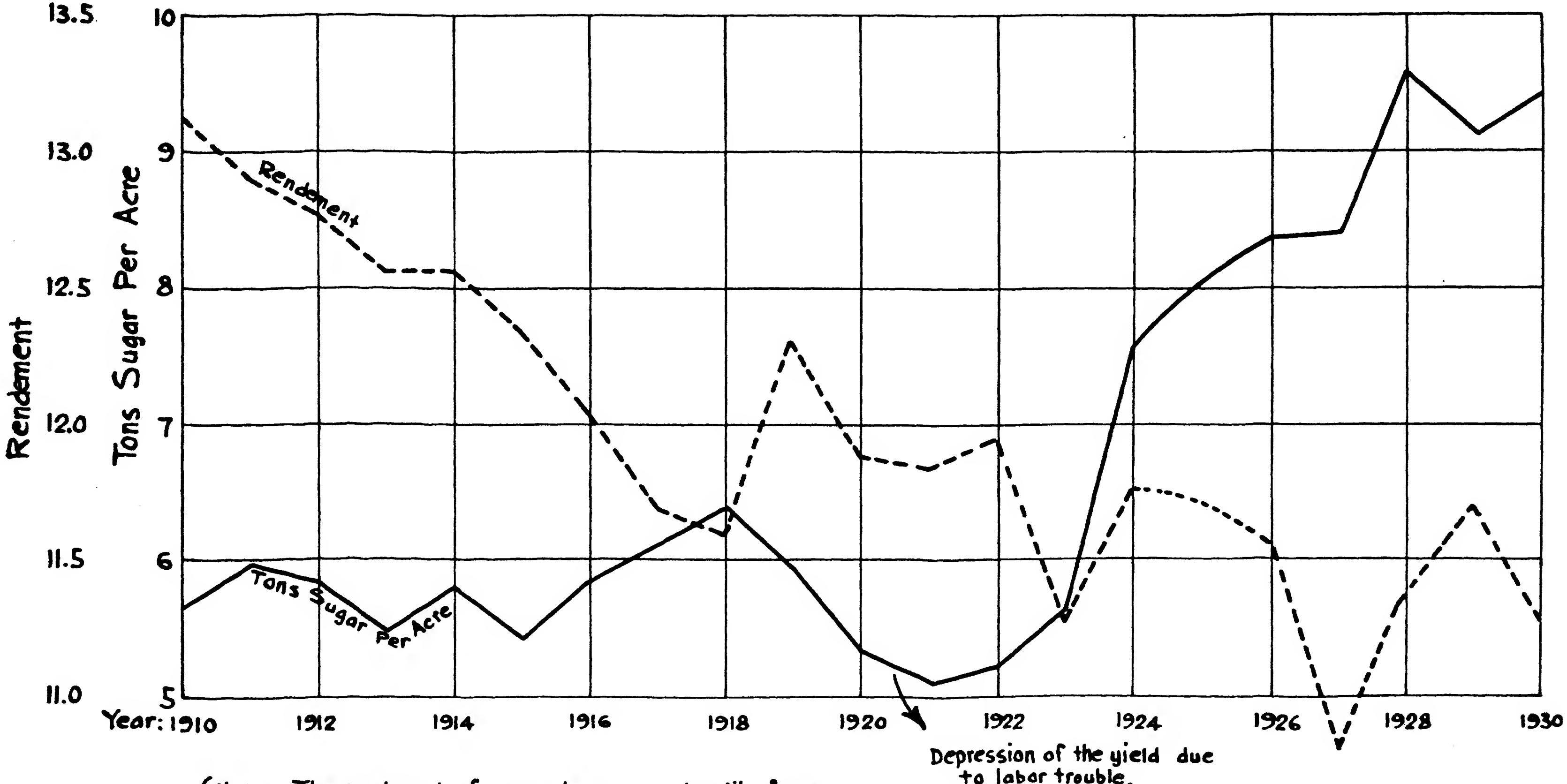
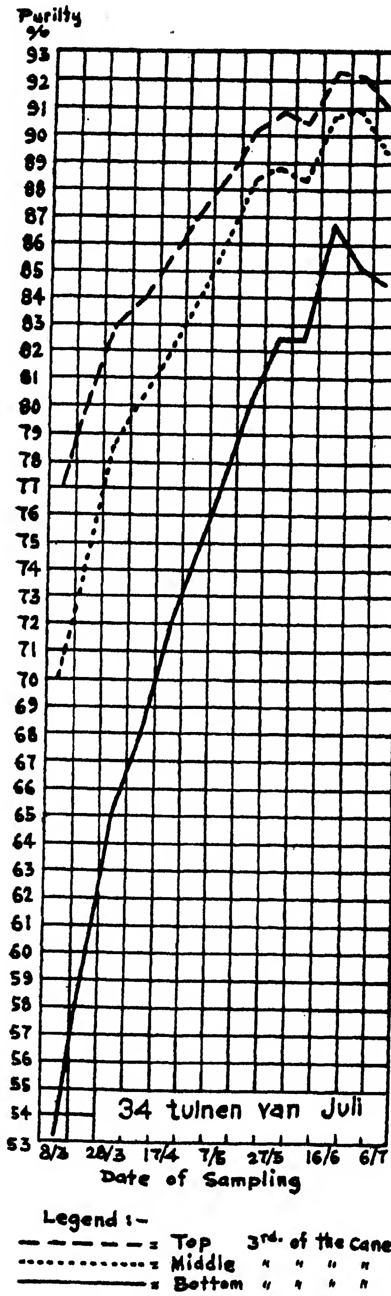
The Production Of Sugar Per Acre In Oahu Compared To The Average Quality Of Juice From 1910 To 1930.



(Note:- The rendement of cane decreases steadily from 1910 to 1930 while the yield of sugar rises just as steadily).

Fig. 1



(After Kuyper in Java Archief)

Fig. 2. Note the steady improvement in the purity of juice of the bottom third, a long time after the attached leaves had died off.

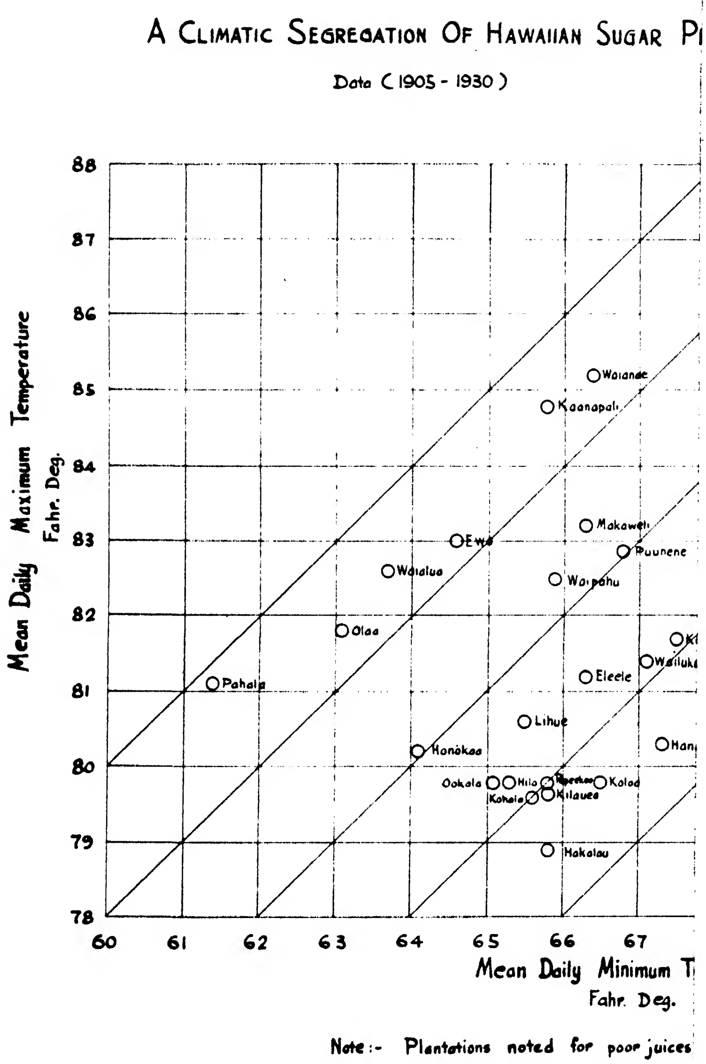


Fig. 3. In this figure the plantations have been located
minimum temperature. For example, Ewa is seen to have an
mum of 64.6° F. Diagonal lines have been drawn through
mum and annual minimum temperature. In the case of Ewa
close to the 18° line of range of temperature. Java and Cub
son. This figure and its implications are dealt with in grea

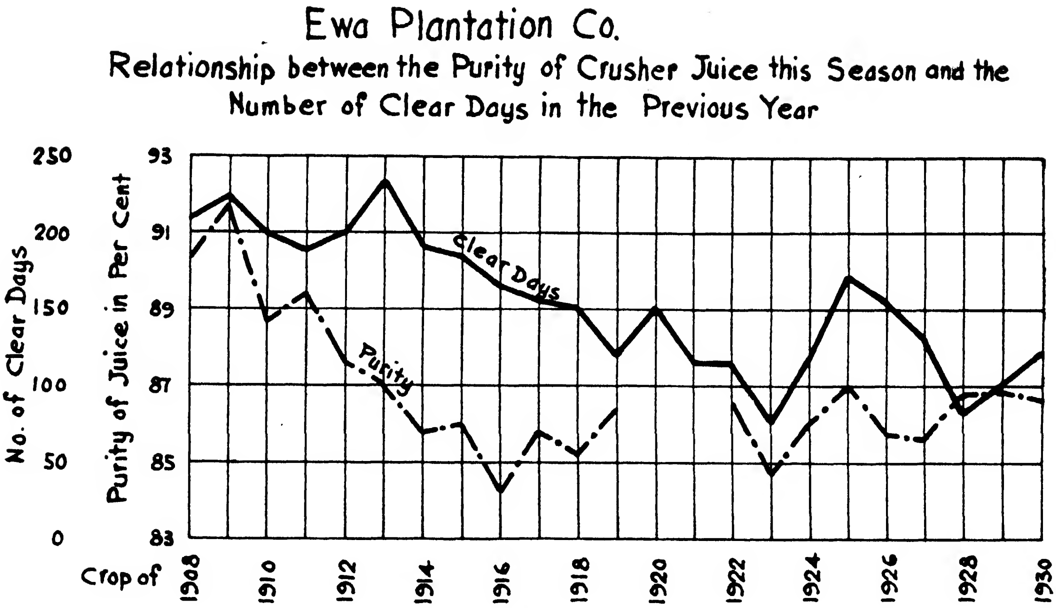


Fig. 5

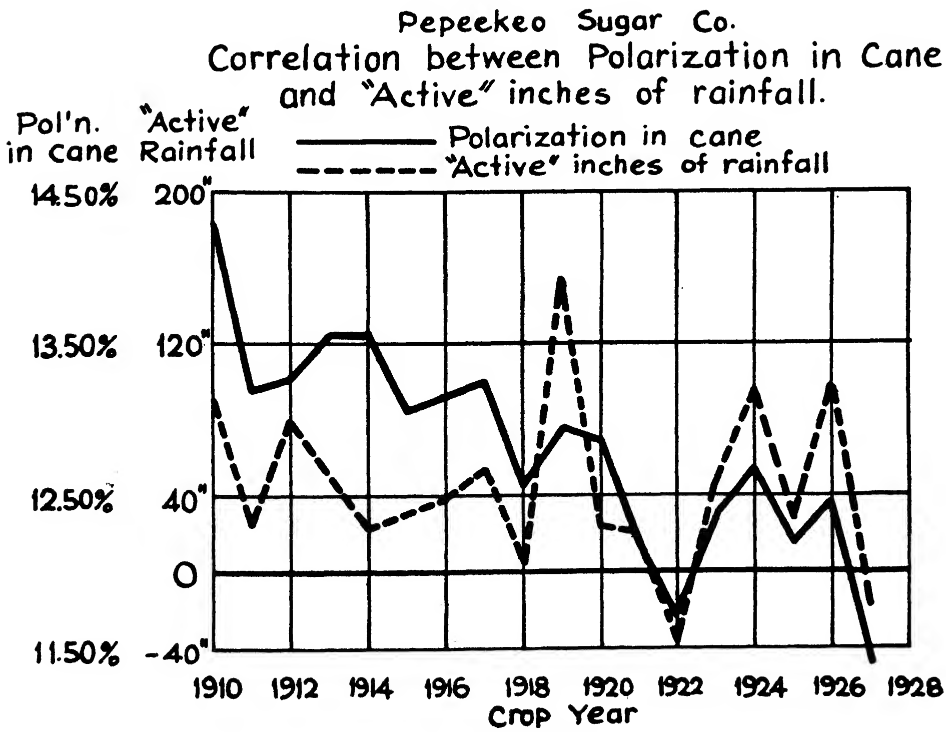
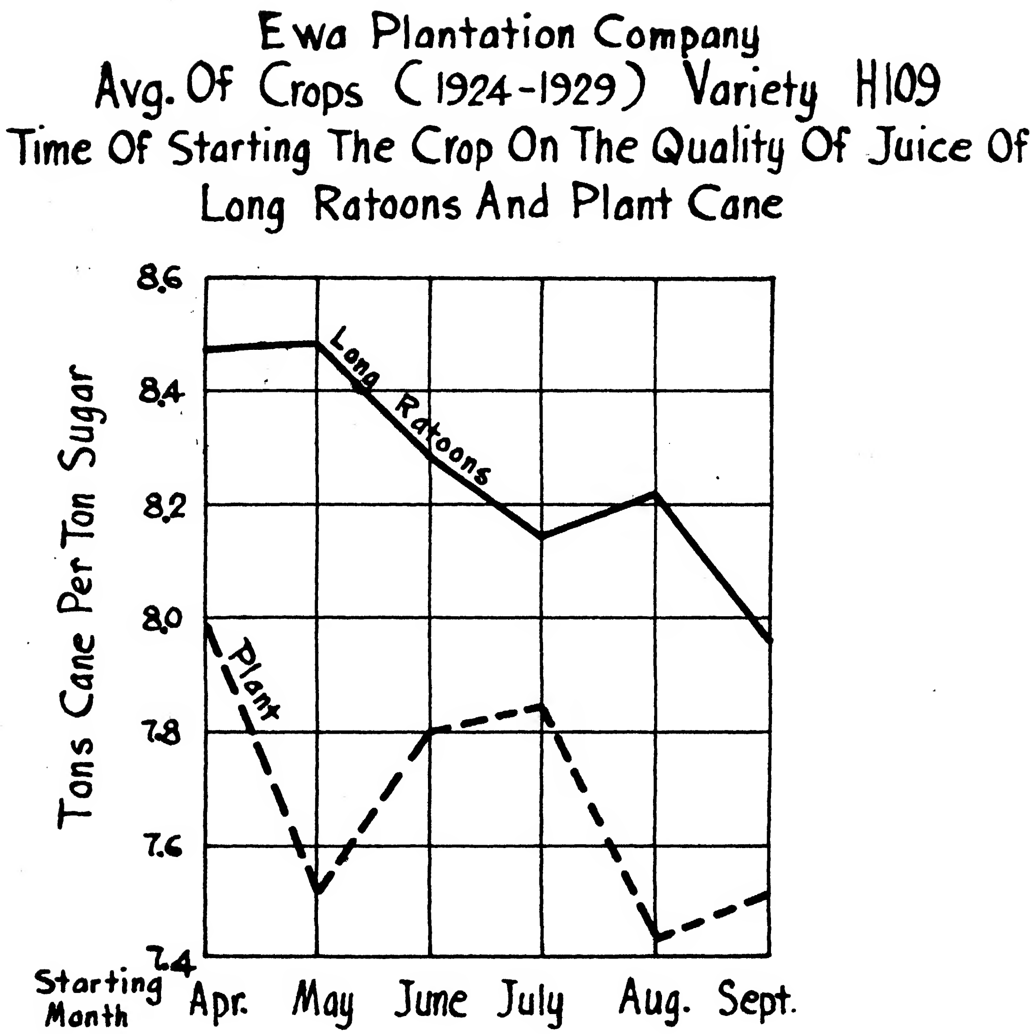


Fig. 6. "Active" inches of rainfall takes into consideration both the amount of rainfall in the growing season and the amount in the harvesting season. Plentiful rain in the growing season and a comparatively dry ripening and harvesting season make for good juice in unirrigated plantations. Details are to be found in *Hawaiian Planters' Record,* Vol. XXXII, 1928, p. 105.



(Note:- The quality of the juice tends to be better as the season of starting approaches the summer months).

Fig. 7

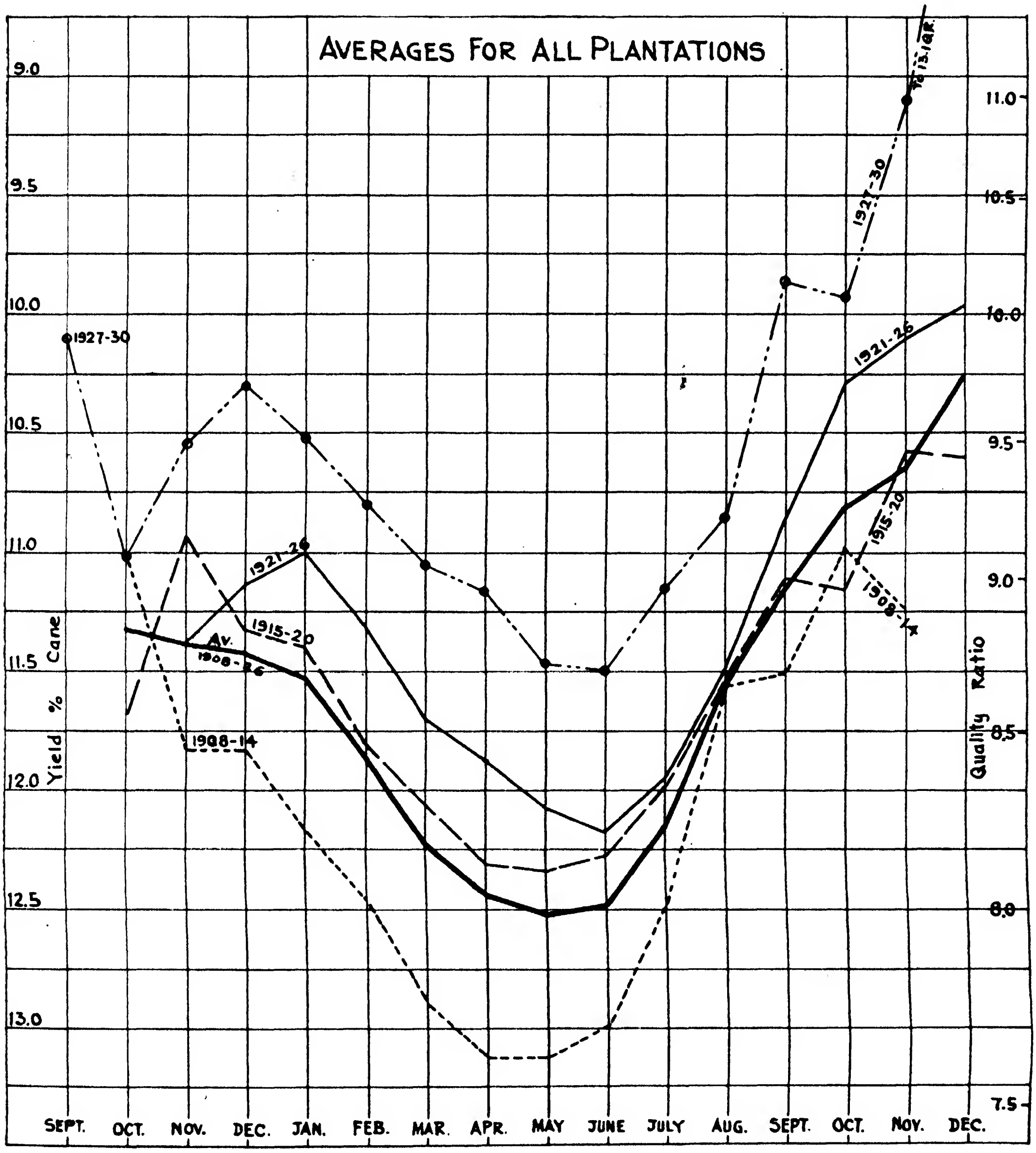


Fig. 8. In these Islands, canes harvested around the months of April, May and June give better juices, in general, than cane harvested at any other period—this, regardless of other factors.

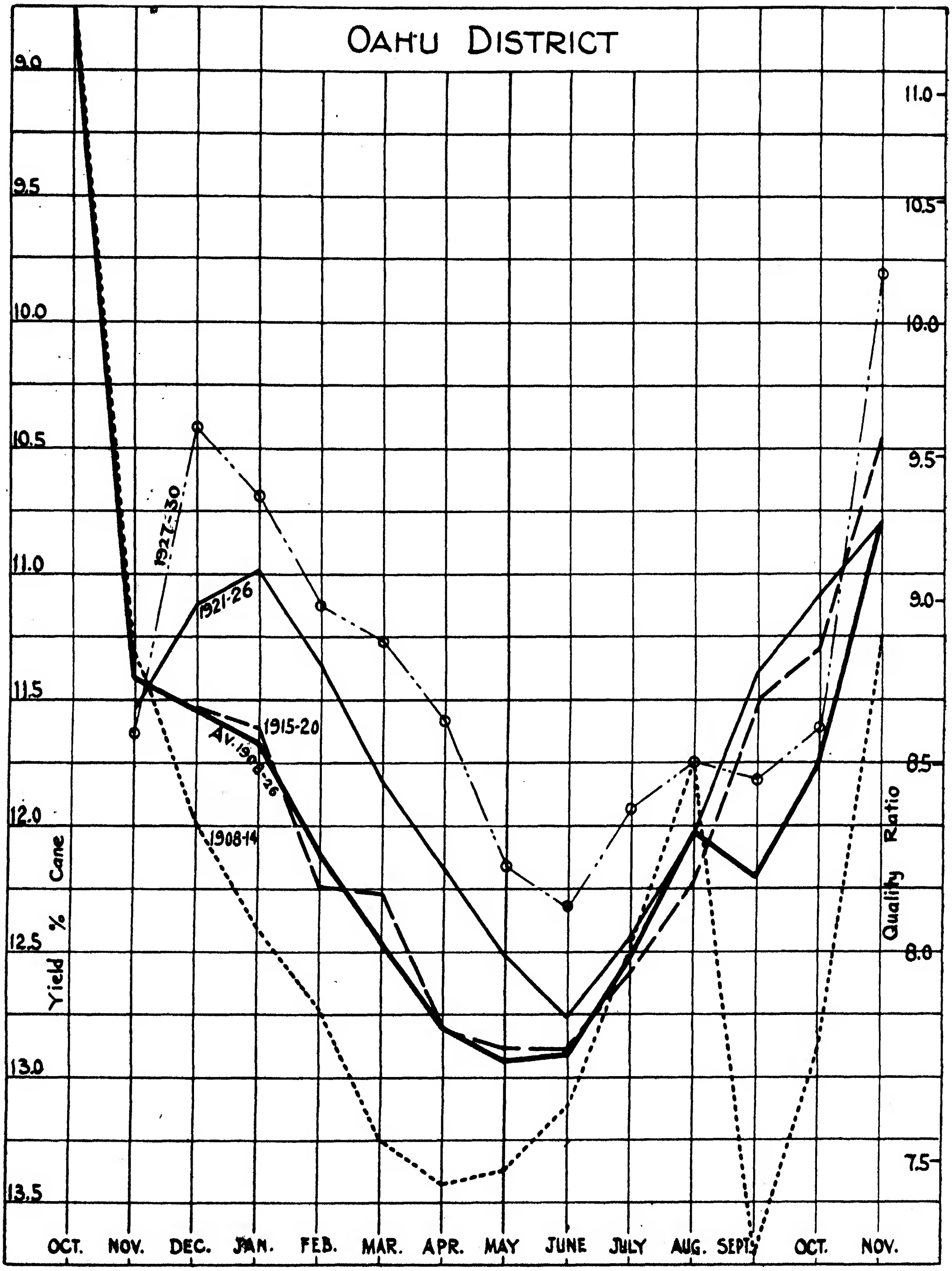


Fig. 9 (a). In 1908-1914, the best juices were obtained from cane harvested in April, in 1915-1920 in May, and in recent years in June. It is suggested that this shift of two months might be due to delayed maturity of cane under our present cultural conditions.

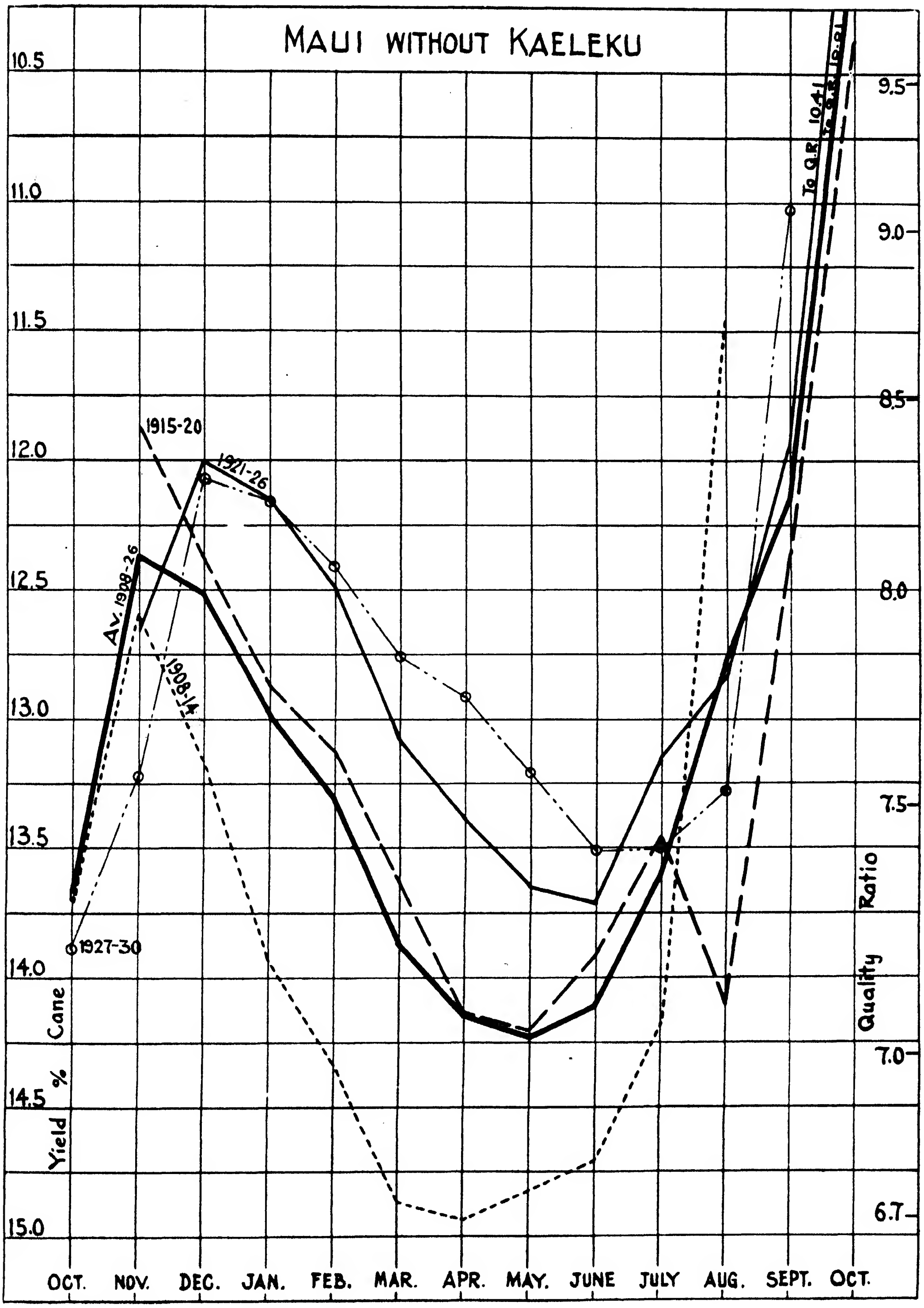


Fig. 9 (b). For explanatory legend see page 194.

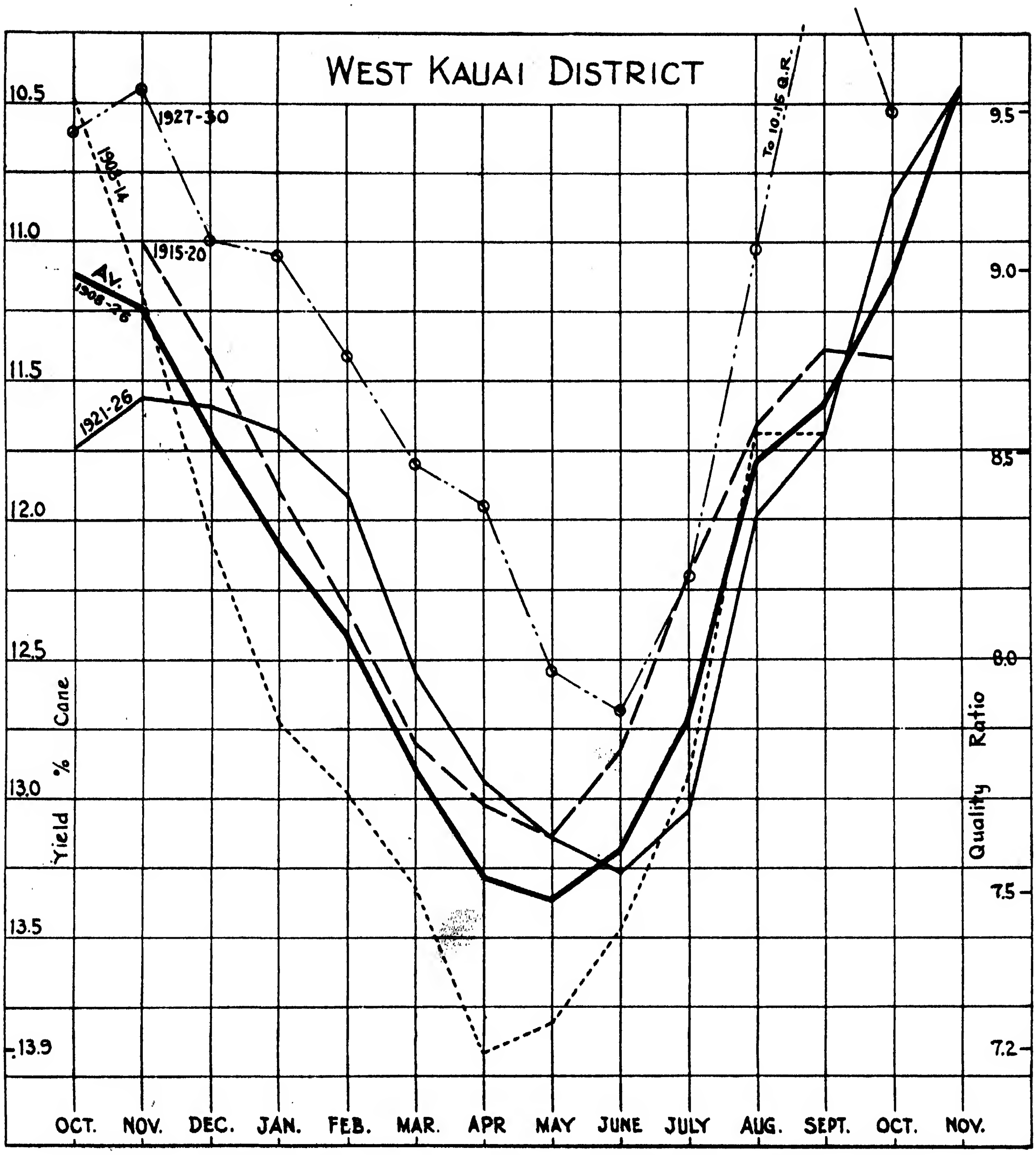


Fig. 9 (c). For explanatory legend see page 194.

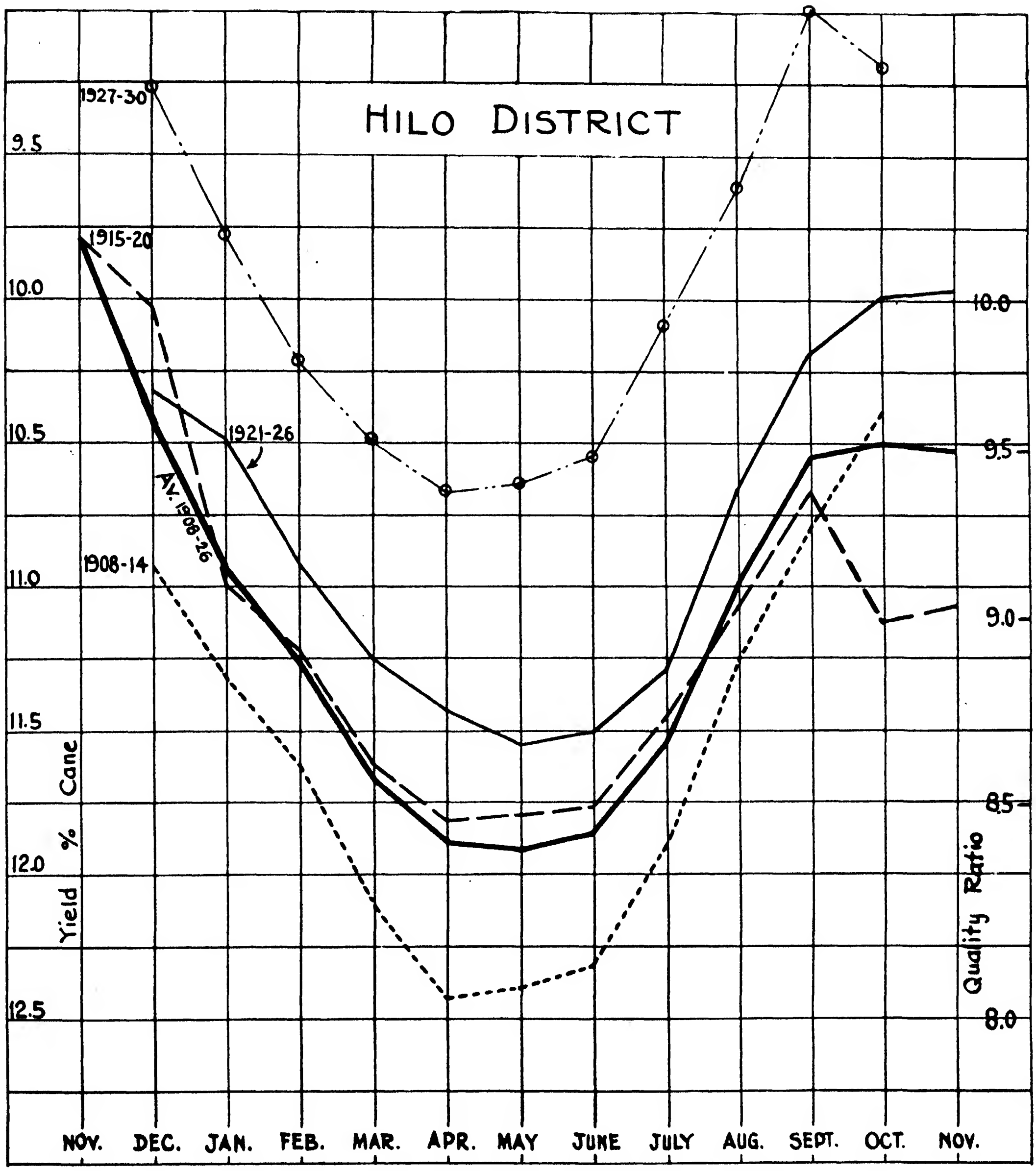


Fig. 9 (d). For explanatory legend see page 194.

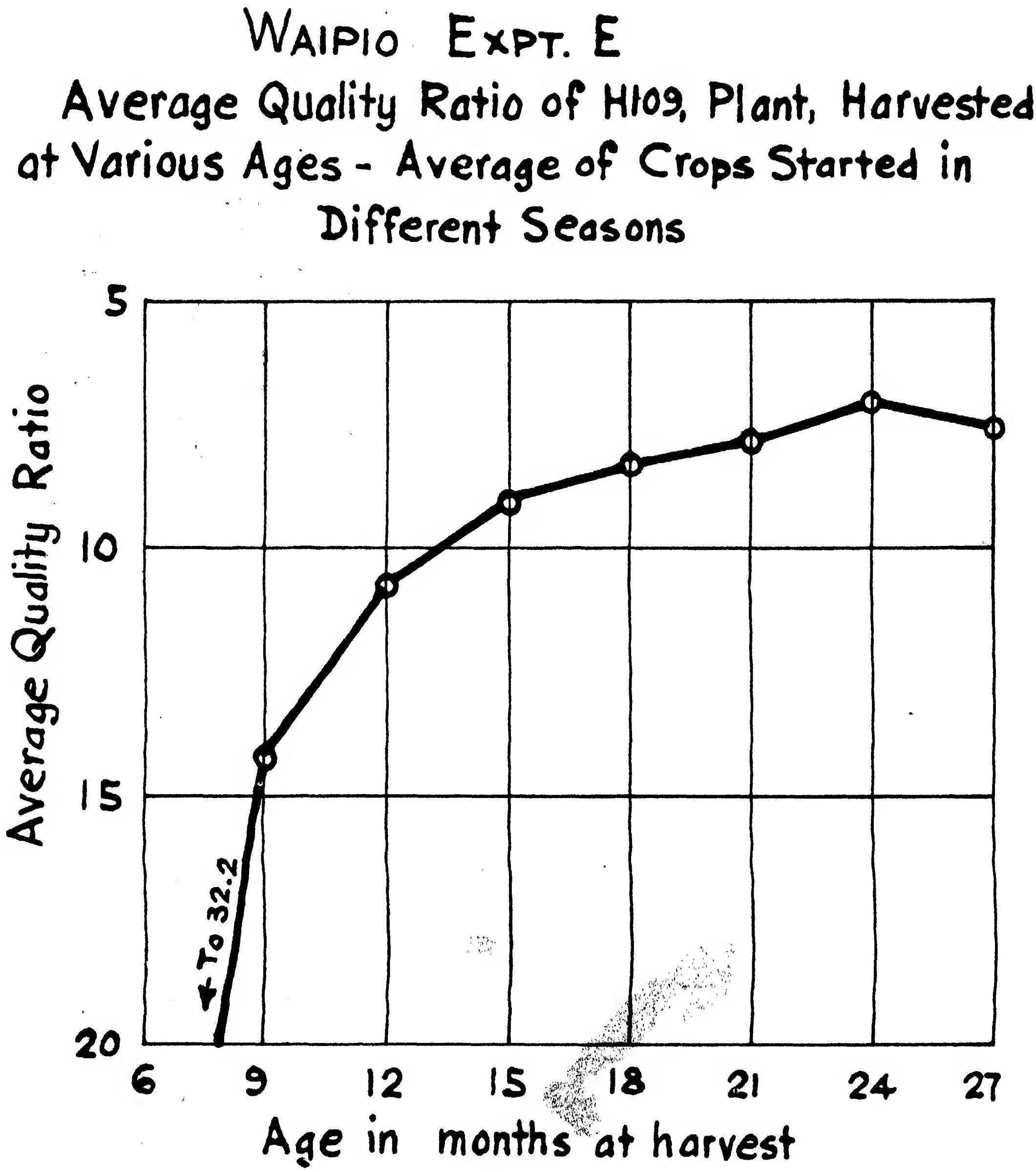

WAIPIO EXPT. E
Average Quality Ratio of H109, Plant, Harvested at Various Ages - Average of Crops Started in Different Seasons
Average Quality Ratio
5
10
15
20
To 32.2
6
9
12
15
18
21
24
27
Age in months at harvest

Fig. 10

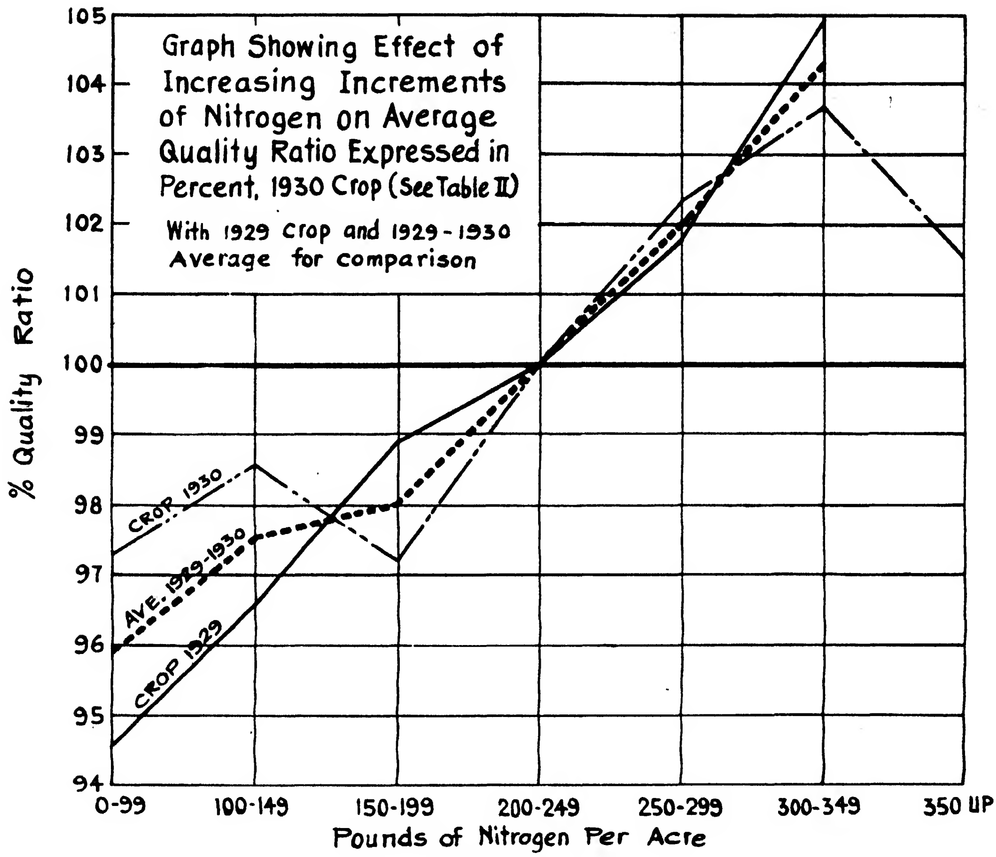

Graph Showing Effect of Increasing Increments of Nitrogen on Average Quality Ratio Expressed in Percent, 1930 Crop (See Table II)
With 1929 Crop and 1929-1930 Average for comparison
% Quality Ratio
105
104
103
102
101
100
99
98
97
96
95
94
CROP 1930
AVE. 1929-1930
CROP 1929
0-99
100-149
150-199
200-249
250-299
300-349
350 UP
Pounds of Nitrogen Per Acre

Fig. 11

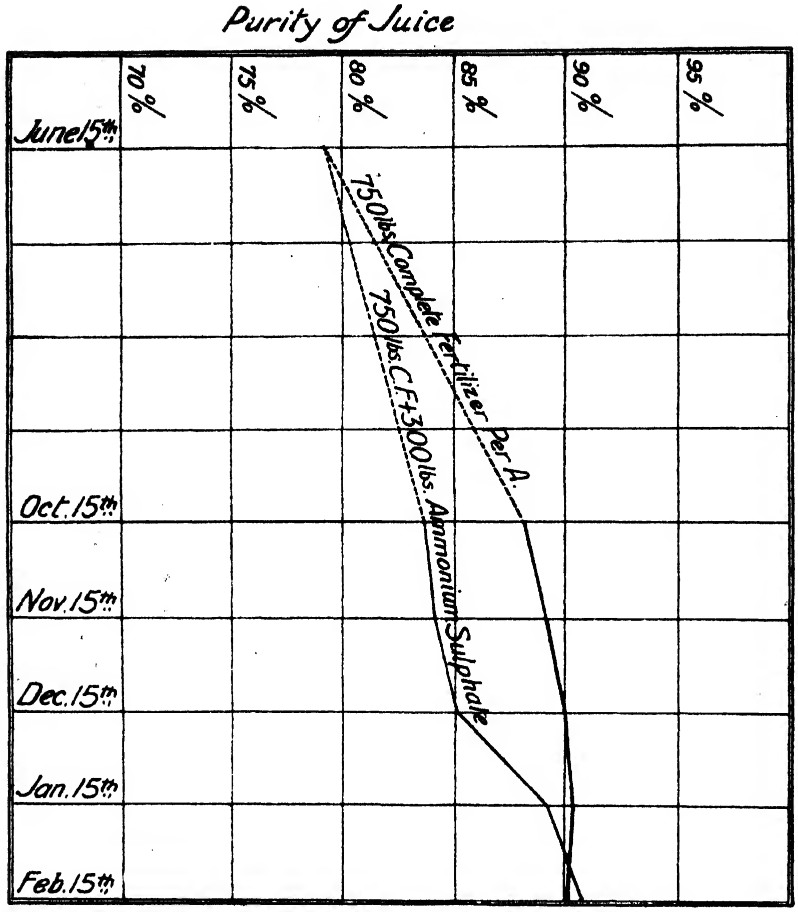
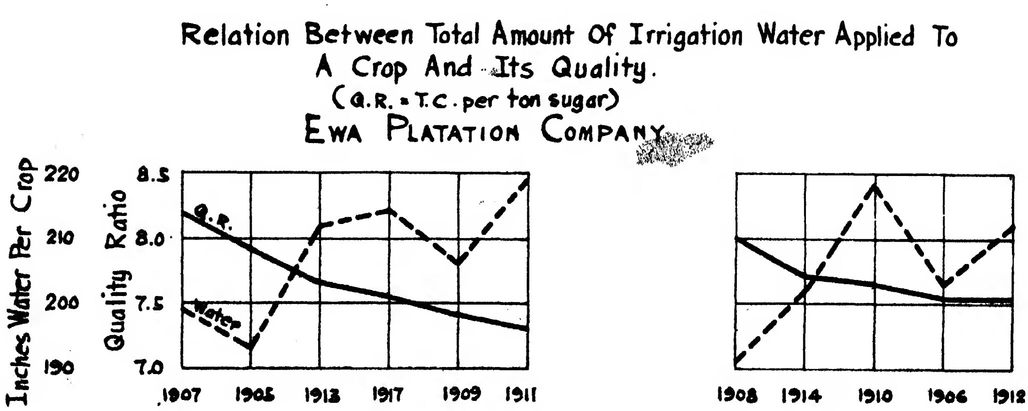


Fig. 12. Spring dressing of 300 lbs. N applied in May, 1909—all plots harvested in February, 1910, at the age of 24 months. Total nitrogen 180 lbs. per acre. Note that the plots receiving spring dressing are much slower in reaching maturity, but in February, 1910, both the treatments gave the same quality of juice.



(Data from "The sugar yields in a typical irrigated plantation of Hawaii, the Ewa Plantation Co, Planters' Record, Vol. XXXIV April, 1930)

Fig. 13

Sugar Prices

96° Centrifugals for the Period Dec. 16, 1930, to March 12, 1931.

Date	Per Pound	Per Ton	Remarks
Dec. 16, 1930	3.25¢	$65.00	Cubas.
" 23	3.23	64.60	Philippines.
" 24	3.22	64.40	Cubas.
" 29	3.145	62.90	Cubas, 3.15, 3.14.
" 31	3.25	65.00	Cubas.
Jan. 2, 1931	3.18	63.60	Philippines.
" 5	3.275	65.50	Philippines, 3.25, 3.30; Cubas, 3.30; Porto Ricos, 3.30.
" 6	3.37625	67.53	Philippines, 3.35, 3.38; Porto Ricos, 3.375; Cubas, 3.40.
" 7	3.3833	67.67	Philippines, 3.40, 3.37; Porto Ricos, 3.38.
" 8	3.40	68.00	Porto Ricos; Philippines.
" 12	3.41	68.20	Porto Ricos, 3.40; Cubas, 3.42.
" 13	3.39	67.80	Porto Ricos, 3.38, 3.40; Cubas, 3.40.
" 14	3.38	67.60	Cubas.
" 20	3.40	68.00	Porto Ricos.
" 21	3.39	67.80	Porto Ricos, 3.38; Cubas, 3.40.
" 22	3.40	68.00	Porto Ricos; Philippines.
" 26	3.37875	67.58	Philippines, 3.355, 3.39, 3.37; Cubas, 3.40.
" 29	3.35	67.00	Porto Ricos.
Feb. 3	3.315	66.30	Philippines, 3.30; Porto Ricos, 3.30; Cubas, 3.33.
" 4	3.29	65.80	Porto Ricos, 3.30; Philippines, 3.28.
" 5	3.30	66.00	Cubas; Philippines.
" 11	3.32	66.40	Porto Ricos.
" 17	3.30	66.00	Cubas; Philippines; Porto Ricos.
" 24	3.32	66.40	Cubas; Porto Ricos.
Mar. 2	3.28	65.60	Cubas.
" 3	3.25	65.00	Philippines; Porto Ricos.
" 6	3.23	64.60	Cubas; Porto Ricos; Philippines.
" 10	3.25	65.00	Cubas; Porto Ricos.
" 11	3.275	65.50	Porto Ricos, 3.25, 3.30.
" 12	3.25	65.00	Porto Ricos; Philippines.

THE HAWAIIAN PLANTERS' RECORD

Volume XXXV JULY, 1931 Number 3

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Frederick A. G. Muir:

An historical account of the extremely valuable work of Dr. Muir in the introduction of natural enemies for the biological control of the major insect pests of sugar cane in Hawaii. Chief among these pests were the sugar cane leafhopper, the Anomala root grub, and the New Guinea sugar cane beetle borer. Reference is also made to Dr. Muir's work in systematic entomology, which dealt chiefly with the important group of leafhoppers and their allies. A bibliography of Dr. Muir's published works is included.

Width of Cane Rows:

The question often arises, "How far apart do they make their cane rows in that country, and does the width increase or decrease yields?" In this article we have drawn our data from other countries and present them along with what data we have from our own files.

Climate in Relation to Sugar Production:

This article is a general survey of an admittedly big subject. It shows by means of some interesting and simple charts the great differences in sugar production that can be caused by changes in weather conditions, and suggests that climate be considered a factor of major importance in our cane agriculture.

The Significance of Climatic Differences Among the Sugar Plantations of Hawaii:

Some plantations grow H 109, others Yellow Caledonia; some have generally good juices, others poor—why? It may be due to differences in soil, in water, or other factors. This article brings out certain interesting relationships which seem

to suggest that some of these differences could be due to differences in climatic conditions.

Field Experiment Technique:

The various problems related to the technique of conducting field experiments are dealt with in a comprehensive paper now published with the revisions that followed preliminary circulation inviting suggestions and criticisms.

Notes on Interpreting Experimental Results:

One of the most perplexing problems connected with field experiments is the process by which a logical and proper interpretation of the harvesting results is obtained.

A few of the methods and hints are suggested for excluding the irrational harvesting data and for interpreting the experimental results.

Studies in Experimental Technique:

A study of the data secured from the 1931 Blank Test, harvested at Hakalau Plantation Company, is offered to show how such factors as the size and shape of plot, and the number of replications, can affect the accuracy of our field experiments.

Some Mononchs of Hawaii:

Dealing with the distribution of Mononchus nematodes in the Hawaiian Islands together with preliminary observations upon *Mononchus sigmaturus* and *Mononchus brachylaimus* under cultural conditions, and descriptions of eleven species.

Steer "Dry Lot" Fattening Experiment:

The value of molasses and bagasse as a stock feed was again demonstrated in an experiment at one of the plantations, using steers for "dry lot" fattening. The molasses and bagasse were supplemented by an imported protein concentrate.

Frederick A. G. Muir

THE WORK OF DR. FREDERICK A. G. MUIR IN THE BIOLOGICAL CONTROL OF SUGAR CANE INSECTS IN HAWAII

By O. H. Swezey and F. X. Williams

With the death of Dr. Muir in England on May 13, 1931, ended the career of a man who had devoted his best years to the field of biological control as a method of controlling insect pests. Dr. Muir began this work for the Experiment Station of the Hawaiian Sugar Planters' Association in September, 1905. This was when the sugar cane leafhopper, *Perkinsiella saccharicida* Kirk., was still a serious pest in Hawaii. It was also shortly after the introduction of the leafhopper egg-parasites* by Albert Koebele and Dr. R. C. L. Perkins, from Australia and Fiji. These parasites had not yet shown their ability to cope with the enormous numbers of their host. Mr. Koebele had been working for more than ten years on the introduction of beneficial insects into Hawaii and, being in failing health, wished to retire from active foreign work in the tropics. On his return from Fiji he spent but a short time in Honolulu in the summer of 1905, before leaving for California. Mr. Koebele never came to Honolulu again.

To carry on the work in which Mr. Koebele had been so successful since his arrival in Hawaii in 1893, Dr. Muir was engaged and his services on the staff of the Experiment Station, H. S. P. A., commenced September 1, 1905.

Spending but a short time in Honolulu, Dr. Muir's first foreign trip was to Fiji with the primary object of investigating the economic conditions of the leafhopper in cane fields there. This leafhopper was a different species from the cane leafhopper in Hawaii and was found doing no damage to cane, being kept in check by several natural enemies the most important of which were the egg-parasites mentioned above and which had already been introduced into Hawaii. Another parasite found to have economic value was a stylopid, *Elenchus tenuicornis* Perk. Attempts were made to introduce this parasite into Hawaii, but it failed to attack the leafhopper in the cane fields here. Still another parasite found was a dryinid, *Haplogonatopus vitiensis* Perk., which was successfully introduced into Hawaiian cane fields, and for a time was quite a factor in the control of the leafhopper. After a number of years, however, it became scarce and in recent years has been seldom seen.

On this trip a great deal of time was spent in investigating the cane borer, *Rhabdocnemis obscura* (Boisd.), to discover if possible the cause of its decrease there, for Mr. Koebele had reported such a decrease in Fiji since his visit there in 1892. No natural enemies were found that could be considered responsible for this. Some of the planters believed that the introduction of a hard-rind variety of cane was the chief reason for the decrease of the borer. After six months in

* *Paranagrus optabilis* Perk., *P. perforator* Perk., and *Anagrus frequens* Perk., from Australia in 1904; and *Ootetrastichus beatus* Perk., from Fiji in 1905.

Fiji, Dr. Muir returned to Honolulu, where a few months were spent prior to starting off in July, 1906, for the Orient, where cane leafhopper parasites were investigated in south China in the vicinity of Macao, and inland from Canton. Cane leafhoppers there were found well controlled by egg-parasites similar to those in Australia and Fiji, and there were other valuable enemies as well. Only one of these was successfully introduced into Hawaii. This was a large black dryinid, *Pseudogonatopus hospes* Perk., parasitic on adult leafhoppers. It was reared at the Experiment Station and colonies were distributed to the other Islands, but it was only after nine years that it was known to have become established in Hawaiian cane fields. It never became very numerous, but even in recent years with the leafhopper usually scarce this parasite maintains its existence, and an occasional parasitized leafhopper is to be found, usually wherever any leafhoppers occur.

In February, 1907, a brief visit was made to the Federated Malay States where conditions as regards leafhoppers and their enemies were found to be about as in China. A search was begun for the cane borer beetle, which was continued in Java. Dr. Muir arrived at Batavia on March 10, and spent several months in the different sugar cane sections of Java, without finding any evidence of our cane borer beetle, or any direct parasites on related beetles in banana and palm trees.

On July 21, he left Java for a few weeks' search for the borer in Borneo, returning to Batavia in September from which place another start was made in October, 1907. The search for the natural home of the beetle borer was continued in Amboina and Larat where at last this insect was found in sago and pinang palms and in sugar cane. No success was had in finding parasites for several months, however. Finally in January, 1908, a tachinid fly was found attacking the grubs or larvae of this borer. Eight months were then spent at Amboina in studying this parasite and breeding it for shipment to Honolulu; but as the parasite could not survive such a long journey attempts were made to establish a relay station at Hongkong. This station, which was to have been conducted by F. W. Terry, was not successful as the tachinids always died en route. Finally Dr. Muir tried taking living material with him to Hongkong, but the flies all died the day before his arrival. This venture having failed, Dr. Muir left Hongkong in November, 1908, for further explorations, visiting Ceram and Makassar, en route to New Guinea where he landed at Port Moresby in April, 1909. Here for the first time the tachinid parasite, that was breeding so well on the borer grubs in palm trees at Amboina, was found attacking a high percentage of the borer grubs in sugar cane. At once preparations were made for stocking cages with borer-infested cane in which the borers were to be parasitized, and brought to Honolulu. Several months were required for this, and when eventually the cages were in readiness for the long journey, Dr. Muir fell ill with typhoid fever just prior to leaving Port Moresby, New Guinea, so that on arriving at Brisbane, Queensland, he was compelled to go to a hospital where he remained for five weeks. His cages were forwarded to Honolulu, arriving there September 15, 1909. Over 200 of the tachinid flies had matured en route, but lacking the personal care that had been planned for them, all had died before

their arrival in Honolulu. Thus is recorded another failure in the introduction of this parasite.

As soon as he had recovered sufficiently in the Brisbane hospital, Dr. Muir came on to Honolulu for further recuperation, arriving about the end of October, after an absence from Honolulu of three years and three months most of which time was spent in tropical jungles where he was exposed to the dangers from wild animals, venomous snakes and insects, as well as to tropical diseases prevalent in those regions.

At once plans were made for further attempts to introduce this parasite on the cane borer. Dr. Muir left Honolulu, January 8, 1910, on the final endeavor which resulted in the transportation of the living parasite to Honolulu and its establishment in the cane fields of Hawaii. The procedure this time was the establishing of a relay breeding station at Mossman, Queensland, cared for by J. C. Kershaw. In cages here the tachinid was bred from material brought by Dr. Muir from New Guinea. Of the first generation of parasites reared in these cages, a portion was taken in the puparium stage to Fiji, where at Nausori another relay breeding station was established. From the next generation of parasites produced here, living material was brought to Honolulu by Dr. Muir on August 16, 1910. Mr. Kershaw arrived a month later with more material reared in Fiji. From both of these lots there were sufficient adult parasites to allow some to be liberated in a few cane fields, while others were retained for breeding in cages. Altogether, over four years were occupied on this project; from the beginning until living parasites were landed in Honolulu. The results obtained in checking the cane borer after the parasite was established and fully distributed, more than justified the time, effort and expense involved.

Staying a short time, until the breeding of the tachinid was well started, Dr. Muir sailed from Honolulu, October 4, 1910, for a well-earned leave, going to England for a year, and returning to Honolulu, October 11, 1911.

The next large project undertaken by Dr. Muir, was the endeavor to find and introduce natural enemies of the cane root grub, *Anomala orientalis* (Waterhouse), which in 1912 was found established in cane fields in the Pearl Harbor district of Oahu. There was little or no encouragement to be had from previous efforts to control root grubs by natural enemies in other parts of the world. However, after duly considering the situation, Dr. Muir believed that an attempt should be made to control the spread of Anomala in our cane fields by this method. He left Honolulu for Japan, March 28, 1913, that country being the home of *Anomala orientalis.* A number of valuable natural enemies were found working on Anomala there and efforts were made to introduce some of them here, but none ever became established. After about a year in Japan, search was made in Java, Formosa and the Philippines for parasites of closely related species of root grubs that might possibly be utilized against Anomala. The breaking out of the World War disturbed transportation from those regions, and it was found that the Philippines was the most favorable place in which to work and to secure dependable transportation for consignments of parasites. A large number of root-grub enemies were studied in the Philippines, headquarters being established at the College of Agriculture at Los Baños, where every facility for the work was

rendered. Dr. Muir was assisted in the work here by H. T. Osborn and Dr. F. X. Williams, and large quantities of some of the parasites were reared for shipment to Honolulu; many consignments being made during 1915, 1916 and 1917.

Of the numerous parasites of several kinds that were handled, *Scolia manilae* Ashmead, the wasp which parasitizes the Anomala grub, was the only one to become established in our cane fields. It was first found established and breeding on Anomala grubs September 16, 1916. In the four years since its discovery, Anomala had spread over a considerable area of cane land adjacent to Pearl Harbor. As soon as Scolia was found established in one field, assistance was given it in spreading throughout the Anomala-infested area. This was accomplished during the next year, and the wasp proved so efficient that attempts to introduce additional parasites on Anomala were discontinued. This project turned out to be the first successful control of a root grub by means of natural enemies.

During the four years involved in this work, Dr. Muir returned to Honolulu once or twice; on one trip, coming via Formosa, he brought some leafhopper egg-parasites, one of which, *Ootetrastichus formosanus* Timberlake, became established and spread throughout the cane fields of the Islands and was an additional factor in the control of the sugar cane leafhopper. It persists to the present time, even when the leafhopper is normally scarce.

On October 31, 1917, Dr. Muir left for England to engage in war service for his native country in the trying days of the World War. He returned to Honolulu a year later on October 28, 1918. In the meantime he had married Margaret Annie Sharp on April 9, 1918, the daughter of Dr. David Sharp, the noted entomologist who contributed much to the study of Hawaiian insects and to the Fauna Hawaiiensis. Mrs. Muir accompanied Dr. Muir on his return from England, and also on his last trip in search of parasites to Australia, which was begun early the next year.

Although there now existed a fairly satisfactory control of the sugar cane leafhopper by the introduced parasites previously mentioned, nevertheless in a few plantations there were recurrences of leafhopper outbreaks which were of considerable importance. The purpose of Dr. Muir's last trip, May 18, 1919 to June 21, 1920, was to endeavor to find what additional factors controlled the leafhopper in the Queensland cane fields. After considerable research he found that a small bug, *Cyrtorhinus mundulus* Breddin, of the family Miridae lived by sucking the contents of the eggs of the leafhopper. The introduction of this bug into Hawaii was soon accomplished, chiefly from Fiji (where it was known to occur) by C. E. Pemberton the following year September to November, 1920. This bug was reared and colonies distributed for a year, and from thereafter when it became thoroughly established the control of the leafhopper pest in Hawaiian cane fields was practically complete. There have been slight outbreaks occasionally, but the Cyrtorhinus bug was always prompt to find them, and would soon increase to numbers sufficient to regain control. It has been thought that if this bug had been the only leafhopper enemy introduced it might of itself have been able to sufficiently control the leafhopper.

The total results of the major introductions above enumerated have been the saving of millions of dollars to the sugar industry in Hawaii, and the comparative freedom from destructive insect pests in the cane fields.

After returning from the last trip to Australia. Dr. Muir established his home in Honolulu. Much of his time was now devoted to systematic studies in Homoptera, particularly the Fulgoroidea. This is the group which contains the family Delphacidae to which the cane leafhopper belongs. In his travels Dr. Muir made a specialty of studying and collecting sugar cane leafhoppers as well as other related leafhoppers. Many species of these were named and described by him in numerous papers included in the bibliography which follows. He became intensely interested also in the leafhoppers of the forests of Hawaii, and added many species to those already known, these new species of the Hawaiian fauna being published in the *Proceedings of the Hawaiian Entomological Society*. Dr. Muir eventually devoted himself to the study of leafhoppers the world over, and was recognized as a world authority on the leafhoppers of the family Delphacidae. Just before his death he was planning to work up a large collection from South America.

Dr. Muir's health had been undermined by so much time spent in unhealthful tropical jungles, etc., and he went to England at intervals, spending most of the years 1927 and 1928 there. On his return from England, September 12, 1928, arrangements were made for his retirement from active service at the Experiment Station, H. S. P. A. He left Honolulu on November 17, 1928, to make his home in England, and had made preparations for carrying on systematic work there in his favorite family of leafhoppers, which work, however. he was not able to pursue because of his failing health.

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Widths of Cane Rows in Various Sugar Cane Countries

By J. N. P. Webster

Rosenfeld,[1] in a publication of 1920, states:

The question of the best distance to be given between cane rows, in order to allow of the best possible development of the plants consistent with the largest possible yield per acre, is one of much importance and one which has given cause for considerable investigation and discussion. For each kind of plant and soil there should exist a theoretical maximum of the agricultural yield that can be obtained, i.e., each class of soil in each climate is capable, under the best conditions, of producing an exact maximum of well-developed sugar canes, for example, and this maximum can be obtained only under ideal climatic conditions and with perfect cultivation. This maximum also, naturally, can be obtained only by an ideal spacing of the plants, allowing each one to obtain its maximum development; hence, if we have our rows too close together, we shall probably get a great number of inferior plants, and if we have them too far apart we shall probably obtain splendid specimens of sugar cane, but the reduced number of these will fail to give us the tonnage we should have obtained with more plants of normal development.

In Louisiana, Stubbs[2] (according to Rosenfeld's data) has probably done the the earliest experimental work with varying widths of cane rows. The average results of his experiments on one year of plant cane in 1890 and ratoons in the following year are as follows:*

Width of Middles, Ft.	No. of Stalks per Acre	Average Weight of Stalks, Grams	Tons Cane per Acre	Q. R.	Tons Sugar per Acre
3	30,004	1300	45.98	14.48	3.18
4	27,260	1250	40.96	15.58	2.63
5	27,920	1300	43.53	14.33	3.04
6	26,534	1300	40.53	14.96	2.71
7	26,548	1250	39.86	14.05	2.84
8	24,914	1350	39.30	15.45	2.54

He found that up to the time the cane was laid by there was a considerable death of young shoots and this was most noticeable in the close rows in the ratoon crop.

Due to the narrowness of the three-foot and four-foot rows no mechanical cultivation could be given them, but even so, in both the plant and in the ratoon crops the lines spaced 3 ft. apart gave the greater tonnage per acre, followed by the 5-ft. lines.

From the results of the above experiments, the Audubon Sugar Experiment Station adopted the 5-ft. lines for all further experimental work as these were considered most economical for cultural methods.

Stubbs continued the same experiments and the following tables by Rosenfeld, show in part, the cane tonnages obtained:

* For the purpose of convenience in this table and following tables, where necessary, the writer has converted hectares to acres, etc.

TABLE IV

AVERAGE RESULTS IN LOUISIANA FROM FOUR CROPS OF STRIPED CANE

Width of Middles	Tons Cane per Acre	Q. R.	Tons Sugar per Acre
3 ft.	34.42	14.63	2.35
4 ft.	33.44	14.69	2.28
5 ft.	36.92	14.51	2.54
6 ft.	34.29	13.64	2.51
7 ft.	34.19	13.44	2.54
8 ft.	31.90	14.58	2.19

TABLE V

AVERAGE RESULTS IN LOUISIANA FROM THREE CROPS OF PURPLE AND STRIPED CANE

Variety	Width of Middles	Tons Cane per Acre	Q. R.	Tons Sugar per Acre	Average of Two Varieties: Tons Cane per Acre	Average of Two Varieties: Q. R.	Average of Two Varieties: Tons Sugar per Acre
Purple	3 ft.	31.82	13.95	2.28	33.82	13.36	2.53
Striped	3 "	35.82	12.77	2.81			
Purple	4 "	32.02	13.67	2.34	31.46	13.67	2.30
Striped	4 "	30.90	13.66	2.26			
Purple	5 "	32.14	13.68	2.35	30.60	14.00	2.19
Striped	5 "	29.07	14.32	2.03			

TABLE VI

AVERAGE RESULTS FOR TWO YEARS FROM EXPERIMENTS WITH 5- AND 6-FT. ROWS

Variety	Width of Middles	Tons Cane per Acre	Q. R.	Tons Sugar per Acre	Average of Two Varieties: Tons Cane per Acre	Average of Two Varieties: Q. R.	Average of Two Varieties: Tons Sugar per Acre
Purple	5 ft.	37.80	13.08	2.89	38.50	13.56	2.84
Striped	5 "	39.19	14.04	2.79			
Purple	6 "	37.52	13.34	2.81	35.61	13.55	2.62
Striped	6 "	33.69	13.75	2.45			

Rosenfeld states:

Table IV shows that for four years the 5-ft. rows again show the maximum of tonnage, while the very fine rows give the smallest yield once more, with the lowest sugar content and largest percentage of glucose of all of the plots. This latter result, which is quite general in the experiments, is diametrically opposed to the general idea; which is to the effect that the purity of wide spaced cane rows will always be superior to that of rows closer together. There is no doubt, however, that sugar cane is a *sociable* plant, and develops best under normal spacing conditions.

In Table V, we see that the average yield of cane increases as the distance between the rows decreases, and once more the best sugar content and purity correspond to the rows with the narrowest middles, although the differences in the contents of the juices are very small.

Table VI gives the average results for two years of further experiments made by Stubbs in 1892 and 1893, with both the purple and striped cane with distances between the rows of 5 and 6 feet, which were the distances most discussed in Louisiana at that time. The cultivation was, it is needless to say, identical in all of the plots, and the

results embrace one crop of plant and one of stubble from the same plantation. Once more the 5-ft. rows show up best in tonnage of cane, and in content of sugar in the juices, and the experiment serves to confirm the opinion that, while it cannot be said at just what distance the cane will give the best results in tonnage and purity, there is at least no advantage in having the middles any wider than is necessary for the easy entrance of cultivation machinery.

Some results of experiments at the Tucuman Sugar Experiment Station are also given by Rosenfeld. These were commenced in 1910 by Prof. R. E. Blouin and continued by the author and later by Dr. W. E. Cross.

The first experiment was started in 1911 and continued in the ratoon crop for 1912.

Table IX, Part II, shows the "Average Results for the Two Years" and is, in part, as follows:

Sub Plat	Width of Middles	Average Weight of Stalks, Grams	Tons Cane per Acre	Q. R.	Tons Sugar per Acre
1	3 ft.	690	14.57	12.7	1.15
2	4 "	730	15.58	12.0	1.30
3	5 "	740	13.62	12.5	1.09
4	6 "	790	15.07	12.8	1.18
5	7 "	680	12.20	12.6	.97
6	8 "	700	10.55	12.6	.84

Rosenfeld states:

The average yields for the two years give the place of honor in production of sugar per hectare to the 4-ft. rows, followed by the 6-ft. ones. Blouin[3] (according to Rosenfeld) concluded from these experiments that, for questions of cultivation, the distance between the rows should not be less than 5 ft., and for questions of yield, more than 6 ft., recommending an average of 5½ ft.

The following table shows the average results of one year of plant cane and three years of ratoons of P. O. J. 36 grown at the Tucuman station using varying widths of lines:

TABLE XI

AVERAGE YIELDS IN P. O. J. 36 EXPERIMENT FOR FOUR YEARS

Width of Middles	Average Weight of Stalks, Grams	Tons Cane per Acre	Q. R.	Tons Sugar per Acre
3 ft.	654	29.87	12.40	2.41
4 "	714	31.24	11.88	2.63
5 "	776	29.98	12.19	2.46
6 "	809	30.04	11.87	2.53
7 "	832	30.55	12.08	2.53
8 "	804	27.48	11.26	2.44

Cross[4] (according to Rosenfeld) concludes:

These results with the P. O. J. 36 cane confirm those already obtained in the Experiment Station with the Creole cane, indicating that approximately the same quantities of cane and sugar per hectare are obtained with rows planted at any distance between 3 and 7 ft. . . . The distance to be selected, therefore, should be *the smallest which will*

permit efficient cultivation of the cane plant as well as stubble, with modern cultivation machinery.

Continuing with experiments at the Tucuman station another series was started in 1916 using P. O. J. 213 and the results compiled for one plant crop and two ratoon crops:

TABLE XII

AVERAGE RESULTS FROM THREE CROPS OF P. O. J. 213 CANE

Distance Between Rows—Ft.	Average Weight of Stalks, Grams	Tons Cane per Acre
3	467	20.98
4	498	21.37
5	495	20.30
6	509	19.47
7	517	18.98
8	543	19.80

Rosenfeld states further:

Once again we see that there is relatively little difference between the average yields of cane per hectare in the distinct sub-plots, the 3 plots with the smaller distances between the rows having given slightly better yields than the 3 with wider middles. The average size of the stalk has also increased again in direct proportion to the distance between the rows. Cross calls attention to the fact that this increase in weight of stalk is due to greater thickness of the canes rather than to increased height.

At the Monte Bello substation, of the Tucuman station, plots were laid out of approximately two and one-half acres each and one plot was devoted to native purple cane and one to native striped cane for each of the series 5, 6, 7 and 8 ft.

The average results of the plant and ratoon crops are given here, in part:

TABLE XVI—PART II

Subplot No.	Variety	Width of Middles, Ft.	Ave. Wt. of Stalks, Grams	T.C.P.A.	Q. R.	T.S.P.A.	Ave. of Two Varieties T.C.P.A.
1	Striped	5	1080	27.13	15.59	1.74	26.30
2	Purple	5	935	25.48	17.45	1.46	
3	Striped	6	1030	24.85	13.73	1.81	23.57
4	Purple	6	955	22.27	14.56	1.53	
5	Striped	7	1100	23.77	18.72	1.27	20.94
6	Purple	7	920	18.12	14.16	1.28	
7	Striped	8	1180	20.49	14.23	1.44	18.84
8	Purple	8	900	17.19	12.73	1.35	

To quote Rosenfeld:

The average of the two crops shows a very steady decrease in yield of cane per hectare as the rows were widened, although the average weight of stalk and the juice analyses do not seem to follow any general rule. This experiment, however, very much confirms the conclusions arrived at in former experiments.

In an editorial appearing in the International Sugar Journal for November, 1920,[5] the following criticism of the above paper by Rosenfeld is made:

The paper as a whole appears to be a strong piece of special pleading for the 5-ft. row. It may be that this is insisted on because of local disbelief in its merits, but we have formed the opinion that, considering the great differences in the growth of varieties of cane, the time they are in the ground, and the enormous antitheses in climate and other conditions in the sugar-growing countries of the tropics, a somewhat wide latitude should be allowed as to how much soil should be provided for each cane stool. With this proviso, five feet is a very good distance, and has been more or less adopted in a great many places; and the main consideration in its favor, which is strongly insisted on by the writer of the paper, is that, while not leaving the land bare too long, it is possible to cultivate the soil between the rows with modern tractors or horse- and cattle-drawn implements.

A further criticism is made in that plots in the various experiments have not been replicated, but it is granted that this has been partly guarded against by the number of experiments noted.

In 1922, Rosenfeld[6] published another article on the distance between rows in which he brings up to date, experiments conducted at Tucuman since his previous paper. He arrives at about the same conclusions as in his previous paper.

Cross,[7] at Tucuman, published an interesting article (of which we offer a translation here) on the width of cane rows in which he gives the results of experiments carried on over a number of years with the varieties P. O. J. 36, 213, Kavengire and Zwinga. Concluding his article he says:

Studying the final results of these experiments with the four varieties mentioned, we confirm the conclusions previously formed, which were as follows:

(1). The plant cane in the case of canes P. O. J. 36 and P. O. J. 213, give the greatest rendement of cane and of sugar per hectare with narrower rows (3 ft. to 5 ft.). The ratoons of these varieties, with the plant and ratoons of the varieties Kavengire and Zwinga, give the same rendement of cane and sugar per hectare, whenever the distance between the rows is within the limits of 3 ft. and 8 ft. (3 ft. and 7 ft. for P. O. J. 36).

(2). The cane, in narrower rows, has stalks which are more delicate and of less weight than in rows well apart. Also with narrow rows we obtain more stalks per hectare than in wider rows.

(3). In general, the richness of cane is independent of the width of rows.

Continuing with his discussion Cross takes up the economic factors concerned with the width of rows:

From the foregoing results then, what is the best distance to plant cane? In the first place, we see, practically the same rendement of cane and sugar per hectare is obtained from all distances between 3 and 8 ft. (7 ft. for P. O. J. 36). . . . The selection of the distance between the rows will depend, therefore, on the economic factor; we should select the distance which will result in the cheapest production of cane.

After this point of view of the economic production the very narrow rows are not convenient for the following reasons: 1. The cost of planting the cane per hectare is augmented by the greater number of rows and the greater quantity of cane necessary for planting, etc. 2. With narrow widths it is necessary to cultivate the cane only with a shovel, because agricultural machinery is unable to get between them. The cultivation by spade is much more costly than cultivation by machinery. 3. The cane produces stalks more delicate and more numerous and makes harvesting more costly. Cane planted at the greater limits of distance, on the other hand, will close in late in the growing season, thus necessitating a greater number of cultivations than would be required in canes planted in narrower rows. We should not forget, however, that the greater cost of production of cane is that which has to do with the making of furrows, and for this reason,

within certain limits the cost of production per hectare will be less as we reduce the number of rows.

At Tucuman, the Reynoso system of Java was compared with the ordinary method of row planting for a period of 6 years, but from the results Cross[8] concluded that this system was not profitable, except in a few cases, because of its cost.

In other sugar producing countries of the world we find the width of rows varying from 4 to 6 ft. In Fiji[9] the rows vary from 5 ft. to 6 ft., the wider distance to enable tractor work in young cane. Furrows in Peru [10, 40] are spaced about 4½ feet apart.

In Mauritius [11, 12], rows are 4 to 4½ ft. apart and cane is planted in holes, spaced 3 ft. apart, made in the rows. Spacing in South Africa [13, 14, 27] varies from 4 ft. to 6 ft., but the average as a rule is 5 ft. In Queensland[15], the width of row apparently depends on the type of cane, "varying from 4 ft. 6 inches for thin erect canes to 6 ft. for thicker canes. . . . The greater part of the cane planting is in 5 ft. rows."

The width between rows in Northern India [16] is from 1 ft. 6 inches to 2 ft. For other sections of India, Sayer [17, 18] states:

> As a result of the experience gained so far, it may be definitely stated that the optimum distance between rows of cane in this part should be 3 ft. for medium thick canes like Co. 213 and 210, while it should be 2 ft. 6 inches for thin canes. This enables intercultural operations to be performed with ease and also helps secure a good crop.

In St. Croix[20], rows are 4¾ or 5 ft. apart, and in some cases the seed pieces are spaced in the lines. The area occupied by each seed piece is known as a hill. Some work has been done with spacing of lines and seed pieces within the lines, and the following table of results is taken from a recent publication [36]:

			Yield per Acre of			
Plot No.	Distance Between Rows—Ft.	Distance Between Hills—Ft.	Plant Cane Tons	First Ratoon Tons	Second Ratoons Tons	Average Tons
1	3.00	2.0	18.67	9.42	23.21	17.10
2	3.00	2.5	11.60	7.85	19.58	13.03
3	3.00	3.0	14.61	8.73	20.07	14.47
1	4.00	2.0	14.97	6.80	17.82	13.03
2	4.00	2.5	13.37	5.86	17.27	12.17
3	4.00	3.0	12.88	6.85	18.24	12.66
1	4.50	2.0	Data lost	6.17	14.23	10.21
2	4.50	2.5	"	5.91	12.12	9.02
3	4.50	3.0	12.46	5.27	15.29	10.99
1	5.00	2.0	13.65	5.70	18.32	12.65
2	5.00	2.5	14.96	4.40	11.91	10.42
3	5.00	3.0	17.28	3.10	8.50	9.63

No comments on the above results are made in the publication, but it is interesting to note that higher yields are obtained with 3-ft. rows and with seed pieces 2, 2.5 and 3 ft. apart. Rows spaced 3 ft. and seed pieces spaced 2 ft. in the line gave the highest yields in the three crops.

In Trinidad [19], the distance between rows is 5 ft. Depending on the fertility

of the soil, the distance between rows in Costa Rica [21] varies from 5½ to 8¼ ft., while in Brazil [22, 35] rows are mostly 1.2 to 1.5 meters apart, or 4 to 5 ft.

Concerning Formosa, Rosenfeld [23] has the following statement:

The planting is usually done in rows about 42 inches apart, in quite a lot of cases a modified Reynoso system, as in Java, being used, though shallower planting and flatter cultivation is more general. Occasionally one finds double row plantings, i.e., two rows about 18 inches apart on one bank and then a middle about 5 ft. wide to the next bank. In this case cultivation is carried on only on the outsides of the double rows, no attempt being made to cultivate the narrow middles.

Honduras [24] plants its cane in rows usually spaced at 6½ ft.

Concerning the distance between trenches in Java, van Deventer [25] states:

The distance between the planting furrows (trenches) which rarely exceeds 5 feet, decreases to 3 feet on less fertile lands. Smaller distances are not used for crop cane (but occasionally for nursery cane). . . .*

As long as the planting distance is wider than the optimum distance the rendement is little influenced. When, however, very close planting is practiced a lower rendement is obtained than with more distant planting. Besides, the percentage of recumbency increases with closer planting.

The most usual distance between the furrows is 4 ft., but all distances ranging between 3 and 5 ft. are frequently seen, especially in East Java many plantations plant closer than 4 ft., and the same applies to the fields in Central and West Java. At present only a few plantations plant at distances of 4½ to 5 ft. from center to center. . . .

Periodically, experiments with greater planting distances are still being made at different places, some of them reach 8 ft. with double rows, but these attempts are usually abandoned speedily because the sugar yield in double rows is considerably less than in single ones.

H. Atherton Lee [26] in a report says:

Our experiments here in the Philippines very carefully done, have shown us that better yields per hectare are obtained if the cane rows are 1 meter apart (40 inches) than if 1.25 meters (50 inches) or 1.66 meters (66 inches). These results as to the narrower distance between rows giving higher yields per hectare have been fully supported by the studies in Java, and they have gone much further with the subject than we have. The data from more than 1000 experiments shown me by Mr. Demandt, chief of the field service, yield the following conclusions:

1. That the important factor is not so much width between cane rows, or distance between seed pieces, but rather the number of cane stalks which come to maturity per hectare.

2. At this point Mr. Lee states that a variety has an optimum number of stalks per hectare up to a certain point, above which, although cane tonnage will increase, purities will be lowered.

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* With the Reynoso system of trenches as used in Java, consideration should be given the fact that the narrower the trenches the greater is the aeration, considering the area as a whole, of not only the soil removed from the trenches, but, also the wall of soil separating the trenches.

Previous to the crop of cane one to two crops of rice are grown and as these crops require water for their development the land is much water-logged. Consequently any aeration of the soil should do much to enhance its condition both physically and chemically. With the trenches closer together a greater proportion of the total area is spaded, and exposed to aeration, which may account, in part, for the higher yields obtained from closer spacing. (J. N. P. W.)

3. Mr. Demandt's work then showed that by narrowing the distance between cane rows the number of stalks per hectare was easily increased.

4. On the contrary, however, lessening the distance between seed pieces did not have much effect on the number of stalks per hectare.

During the year 1928, Demandt (39) has shown that of a total of 180 experiments with distances between furrows, 157 were with P. O. J. 2878, 8 with D. I. 52, 6 with E. K. 28, and 9 with 5 other varieties.

Further on he states:

Of the 152 different experiments with 218 distinct comparisons 3 ft. is found as the closest distance 33 times, 3½ ft. 108 times and 4 ft. 11 times. The widest distance that was investigated was 5 ft. and it occurred 10 times in these experiments.

In the following table he shows, by percentage, the distribution of the comparisons for various years:

Crop	In Favor of Closer Distance	No Difference	In Favor of Wider Distance
1924	52%	29%	19%
1925	51%	32%	17%
1926	37%	55%	8%
1927	48%	37%	15%
1928	50%	32%	18%

In this respect, the relations have not changed. It has to be considered, however, that this applies only if always about the same number of different distances are being compared. During the last two crops the distribution of the distances examined was the following:

DISTANCES EXAMINED

Crop	3 Ft.	3½ Ft.	4 Ft.	4½ Ft.	5 Ft.	6 Ft.	Remarks
1927	5%	29%	44%	13%	8%	1%	Of all comparisons
1928	10%	41%	41%	5%	3%	...	"

It can be seen immediately that as compared with crop 1927, a shifting has taken place toward the closer distances. Due to the fact that the relations in favor of narrower or closer distances have remained about the same for the two years, it is implied that also in this respect a shifting toward the closer distances is taking place.

The following three graphs from a publication by Demandt (28) are interesting in that they show the relation of the cane and sugar yields to the number of stalks of 3 varieties grown in Java.

From Fig. 1 we see that better juices are obtained up to about 13,500 stalks per acre, after which there is a gradual decline. The cane yield increases steadily up to about 16,500 stalks per acre and then remains constant, while the sugar yield also increases steadily up to 15,500 stalks per acre and then declines due to poorer juices.

The statement is made that the decline in juices is more marked from closer spacing of seed pieces in the line than from closer lines, and also that a higher maximum yield is obtainable by closer lines than by closer spacing of seed pieces.

With D. I. 52, Fig. 2, we find a very slight improvement in juices up to about 16,500 stalks per acre and then a gradual decline. The cane yield increases decidedly up to about 21,000 stalks per acre and then very slowly up to about 25,000 stalks

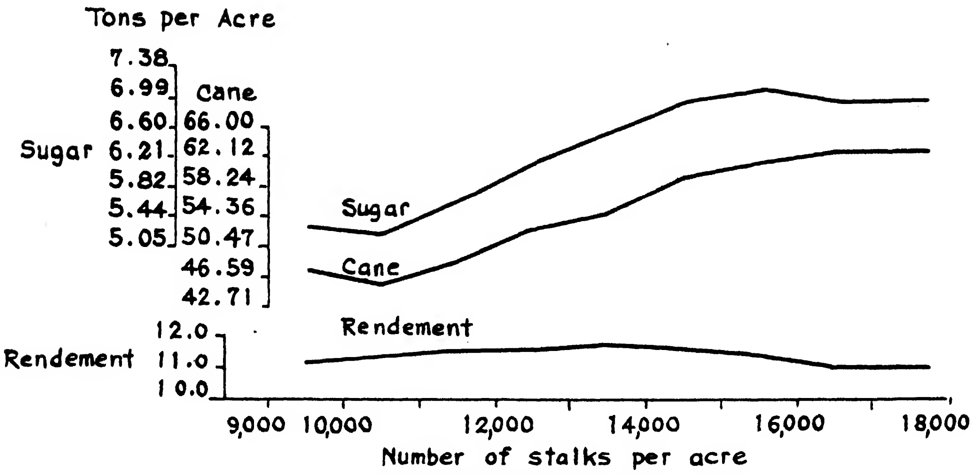

Fig. 1. Average results of 360 spacing experiments conducted with the variety E. K. 28 from 1921 to 1928.

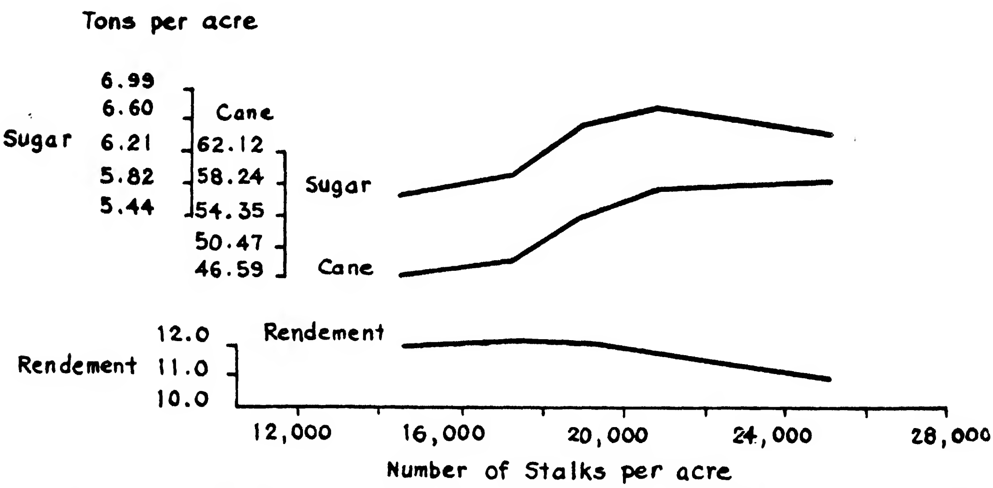

Fig. 2. Average results of 94 spacing experiments conducted with the variety D. I. 52 from 1921 to 1928.

per acre, which is the largest number of stalks recorded. The sugar yield also rises decidedly up to about 21,000 stalks per acre and then there is a decline caused by the poorer juices.

With the juices of P. O. J. 2878, Fig. 3, we find a slightly different condition, for instead of a rise in sucrose content then a gradual decline, as in E. K. 28 and D. I. 52, with increasing numbers of stalks per acre there is a gradual decline. Cane yield increases steadily with increasing stalk numbers and the sugar yield does likewise. The latter because the increase in cane yield more than offsets the decrease in rendement.

Dillewijn [29] by means of a graph, Fig. 4, shows the optimum spacing between lines in the spacing experiments of 1928 and 1929. There were 222 experiments in 1929.

From this graph it can be seen that in 1928 the optimum spacing in 45 and 43 per cent of the total comparisons was found to be 3½ ft. and 4 ft. respectively;

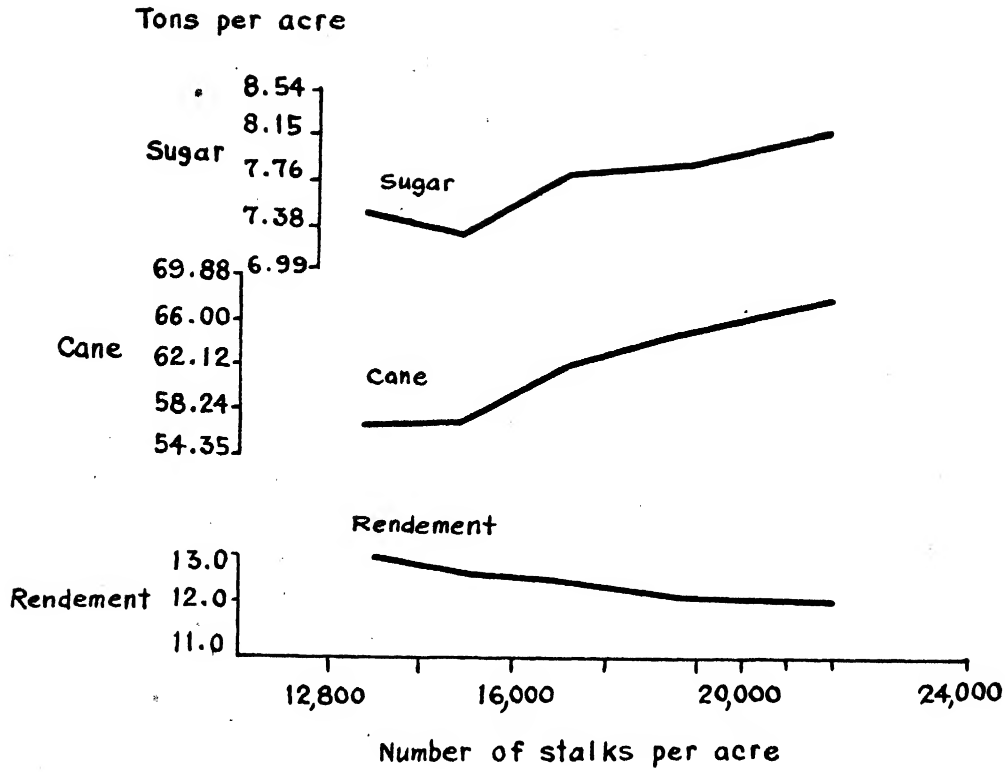

Fig. 3. Average results of 1099 spacing experiments with the variety P. O. J. 2878 from 1927 to 1929.

while in 1929 the optimum spacing was found to be almost 60 per cent for 3½-ft. rows and about 25 per cent for 4-ft. rows.

In the Philippines some experiments were carried out by Locsin [30] to determine what the distance between rows in the Victorias District should be. He found that the narrow rows gave a greater yield of cane and of sugar per acre as shown by the following tables:

I. GASTON HACIENDA

Distance	Plant Tons per Acre		Ratoons Tons per Acre	
	Cane	Sugar	Cane	Sugar
3 ft.	30.18	3.15	24.59	2.89
4 ft.	28.62	2.79	22.63	2.77
5 ft.	29.23	2.82	16.22	1.98

II. MIGUEL HACIENDA

3 ft.	22.00	3.02	24.82	3.58
4 ft.	18.67	2.65	22.09	3.14
5 ft.	17.82	2.45	20.81	2.97

Mr. Lee [31], in his annual report for 1929, gives the results of 2 experiments in width of rows which were very carefully laid out and each had a large number of replications. One was carried on in La Carlota District and the other in the Hawaiian-Philippine Company District.

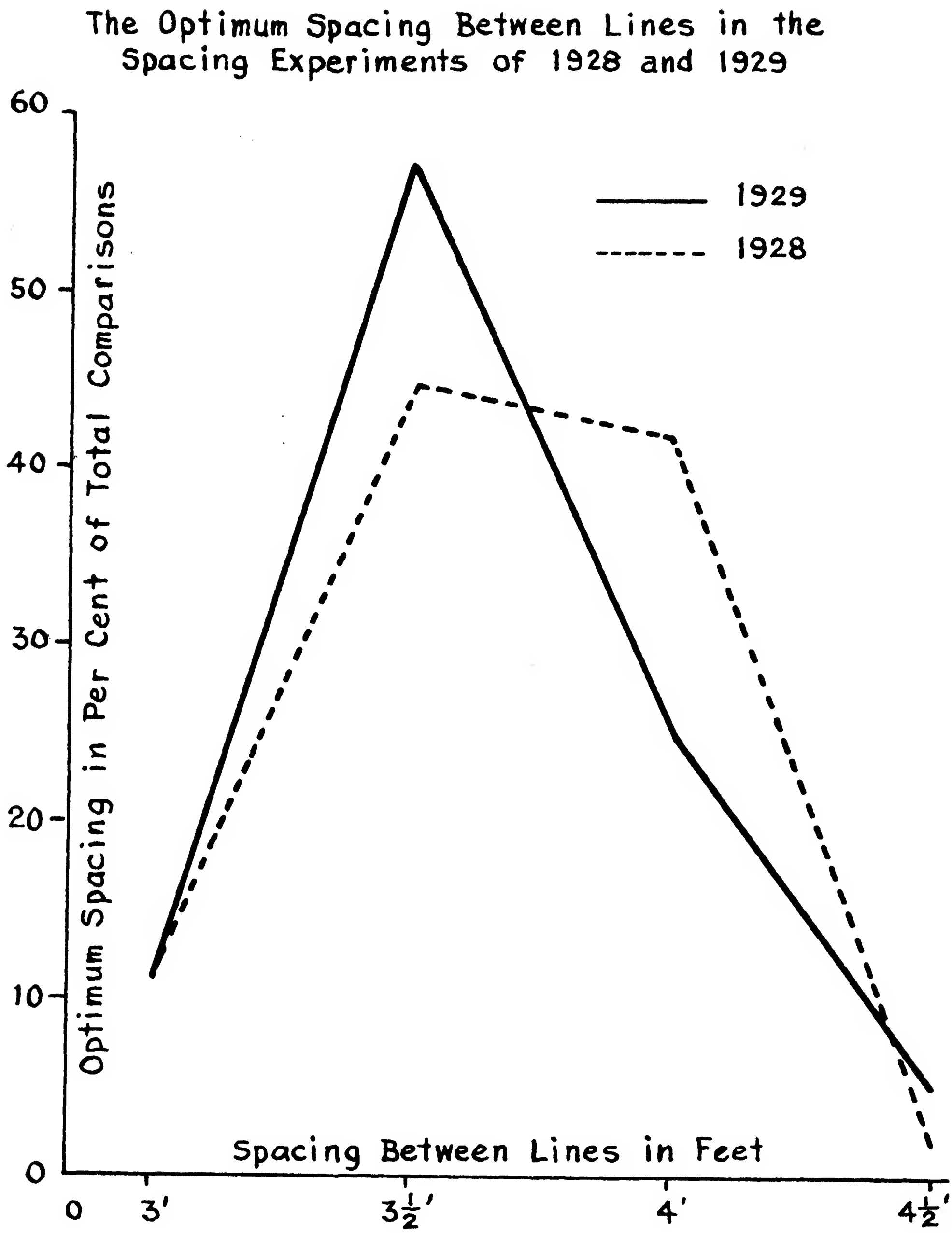

Fig. 4.

The results of the two experiments are given here in part:

LA CARLOTA

No. of Replications	Distance Between Cane Rows	Tons per Acre Cane	Tons per Acre Sugar
20	3⅓ ft.	17.05	2.63
20	4⅙ ft.	16.55	2.55
20	5½ ft.	14.42	2.22

HAWAIIAN-PHILIPPINE COMPANY

No. of Replications	Distance Between Cane Rows	Tons per Acre Cane	Sugar
19*	3⅓ ft.	29.57	3.83
19	4⅙ ft.	28.14	3.80
19	4⅝ ft.	26.21	3.56
19	5½ ft.	25.05	3.54

From the results of the above experiments, Mr. Lee concludes:

These results are in close agreement with the results at La Carlota, pointing to increased yields with closer spacing. . . . It is interesting to note, however, that the width between rows seemed to have no influence on the quality of the juices in the experiment at La Carlota, while there is tangible definite improvement in the quality of the juices with greater spaces between rows in the Maquina experiment. The explanation may lie in the greater yields and hence more crowded condition of the cane at maturity in the Maquina experiment.

In Cuba (32, 33) the method of planting depends more or less upon the kind of land being planted. Where cultivation is possible rows are usually 6 ft. apart. Rows in Porto Rico (34) are spaced at distances from 5 ft. to 6 ft.

In Hawaii, the earliest work on the optimum distance of spacing cane rows is found in a publication by Blouin (37) wherein he gives the results of his experiments. Cultivation, fertilization and irrigation were the same to all plots. No mention is made as to the number of replications nor the number of rows used for each plot.

His results summarized are as follows:

Width of Rows	Per Cent of Sucrose in Cane	Tons per Acre Cane	Sugar
4 ft.	15.09	101.82	15.37
5 ft.	14.33	135.01	19.35
6 ft.	13.14	108.36	14.24
8 ft.	12.62	98.37	12.41

Here the 5-ft. rows show the highest yields in cane and in sugar and Blouin concludes:

Most of the cane rows on the Islands are 5 ft. and these experiments show very forcibly that this is the most economic and advantageous distance to plant. . . .

Local conditions will have to be considered in the absolute determining of the distances between the rows, but every effort should be made to have them conform as nearly as possible to the 5 ft. rows.

In 1914, Experiment J (38) at Waipio was laid out, "To study the varietal differences of Lahaina, Yellow Caledonia and D 1135 in connection with different widths of rows." Four replications of each variety and each width of row were used, each row being spaced 4½, 5, 5½ and 6 ft. We are thus dealing with both a variety test and a width of row experiment.

The results of the experiment were as follows:

	4′ 6″		5′ 0″		5′ 6″		6′ 0″	
Variety	Cane	Sugar	Cane	Sugar	Cane	Sugar	Cane	Sugar
Y. C.	74.2	9.69	82.9	10.17	66.9	8.66	76.4	9.95
D 1135	87.6	11.39	94.2	12.16	85.7	10.96	91.7	11.96
Lahaina	71.9	10.40	74.9	10.72	73.5	10.72	70.9	10.33
Averages	77.9	10.49	84.0	11.02	75.4	10.12	79.7	10.75

Commenting on the above results the statement is made:

> Whereas the average results of this experiment show considerable variation with rows of different widths, at the same time this variation is inconsistent and permits of no very definite conclusion that anything is to be gained by adopting a given width of row within the limits of those under test.

At Kilauea Sugar Plantation Company an experiment (No. 39, Crop 1923) comparing 3-, 4- and 5-ft. lines was harvested with the following results:

Treatment	Tons Cane per Acre
3 ft. lines	21.2
4 "	17.2
5 "	16.8

There were 4 replications each of the 3- and 4-foot lines and 3 replications of the 5-foot lines. Each plot consisted of 12 lines and the cane was plant Badila. There was a gain of practically 4½ tons of cane in favor of the 3-ft. lines over the 5-ft., but whether or not this gain was sufficient to offset increased costs is doubtful.

For the crop of 1932 there is in progress an experiment (Experiment 56M) at Hilo Sugar Company comparing 3-, 4- and 5-ft. rows. The cane is Yellow Caledonia plant at an elevation of 750 ft. There are 3 replications of each of the 4- and 5-ft. plots and 4 replications of the 3-ft. plots.

At Waipio Substation, Experiment B for the 1932 crop compares 2½ ft. spacing of rows with the standard 5 ft. The cane is H 109 and there are 12 replications of each of the two treatments. Another experiment (Experiment J) also for the 1932 crop compares our present lines, 5 ft. wide, with a paddy 10 ft. wide in which 3 lines of cane are planted. There are a total of 14 replications, 7 with H 109 and 7 with P. O. J. 2878.

Throughout the literature we find that in the majority of cases greater yields are obtained when cane is planted in narrow rows, yet why do so few countries adopt narrow rows as a standard?

There are a great many problems to be considered when rows are made narrow. Rosenfeld states: "For each kind of plant and soil there should exist a theoretical maximum of the agricultural yield that can be obtained." This is true, but even so we have to consider the increased costs due to narrower rows.

For instance, taking an average length of line as 35 ft. we have the following numbers of lines per acre at different widths:

Rows	3 ft. apart	415 rows per acre
"	4 ft. "	311 "
"	5 ft. "	249 "

Decreasing the width of rows from 5 ft. to 3 ft. gives 166 more lines per acre and naturally these extra lines increase costs all the way from the amount of seed needed for planting up to shipping a greater tonnage of sugar.

Then too, practically all of the experimental results shown above have been with one-year crops, whereas here in Hawaii our crops average almost two years and results might be quite different.

It seems to the writer that where experiments in width of rows are installed,

careful cost comparisons should be kept in order to determine whether or not the increased tonnage is really as profitable as might appear.

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Climate in Relation to Sugar Production

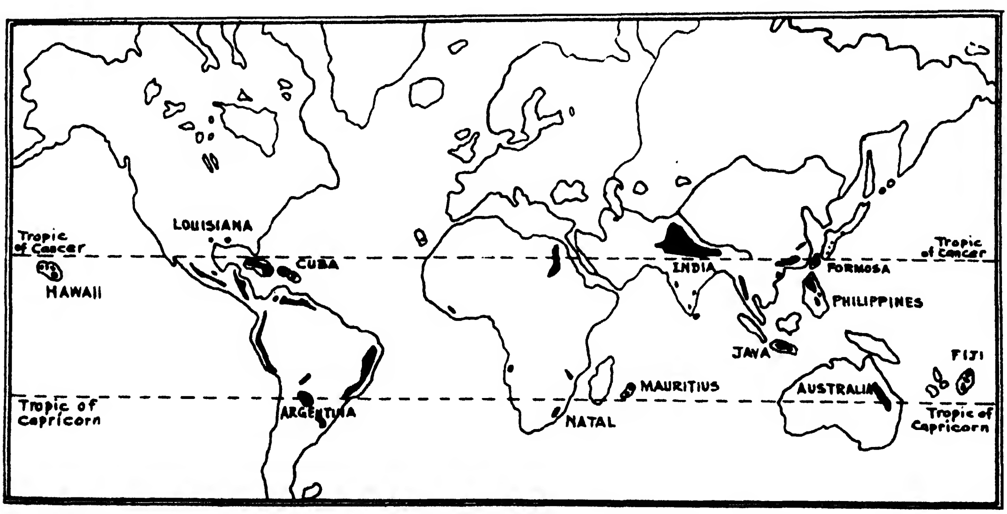
By U. K. Das

Outline

(1). Climate and sugar cane regions.
(2). Weather elements and cane growth.
(3). Weather and sugar yield in Hawaii.
(4). Total warmth and sugar yield at Pepeekeo.
(5). Weather conditions and juices.
(6). Weather and sugar yield in other countries.
(7). Conclusion.

Climate and Sugar Cane Regions

Looking at the world map we find that the principal sugar cane countries lie within the tropics. Louisiana and Argentina on the border of the tropics but outside of it, mark the extreme limits of the sugar cane region. The warm climate of the tropics is thus seen to be essential to profitable cane growing. In fact had it not been for our equable and subtropical climate, the cane would grow faster, ripen in less time and we would have been able to raise a crop in about one year's time like they do in Cuba and Java.



WORLD MAP SHOWING IMPORTANT SUGAR CANE REGIONS

After K. K. Rao, Agricultural Journal of India.

Fig. 1. Sugar cane flourishes best in a tropical climate.

Weather Elements and Cane Growth

Having thus seen that, broadly speaking, climate is the most important factor in determining the suitabillty of any locality for growing sugar cane, and having

found ourselves where we are, what immediately concerns us is not the long range climate but that phase of it which we experience from day to day, namely, the weather.

Sunlight, warmth, rainfall, humidity, wind—all these are the phenomena of weather, and we all know that these do influence our sugar cane crop as they do any other crop. We all speak of drought reducing our yield, cool weather improving our juices. But strange as it may appear, most of us when we think of past weather think of only the harmful ones, the benign influences of good weather are not often recognized or remembered. As that eminent English weather-man, Sir Napier Shaw once said, "As of other benefactors, it may be said of the passing years:

> 'The evil that they do lives after them,
> The good is oft interred with their bones.' "

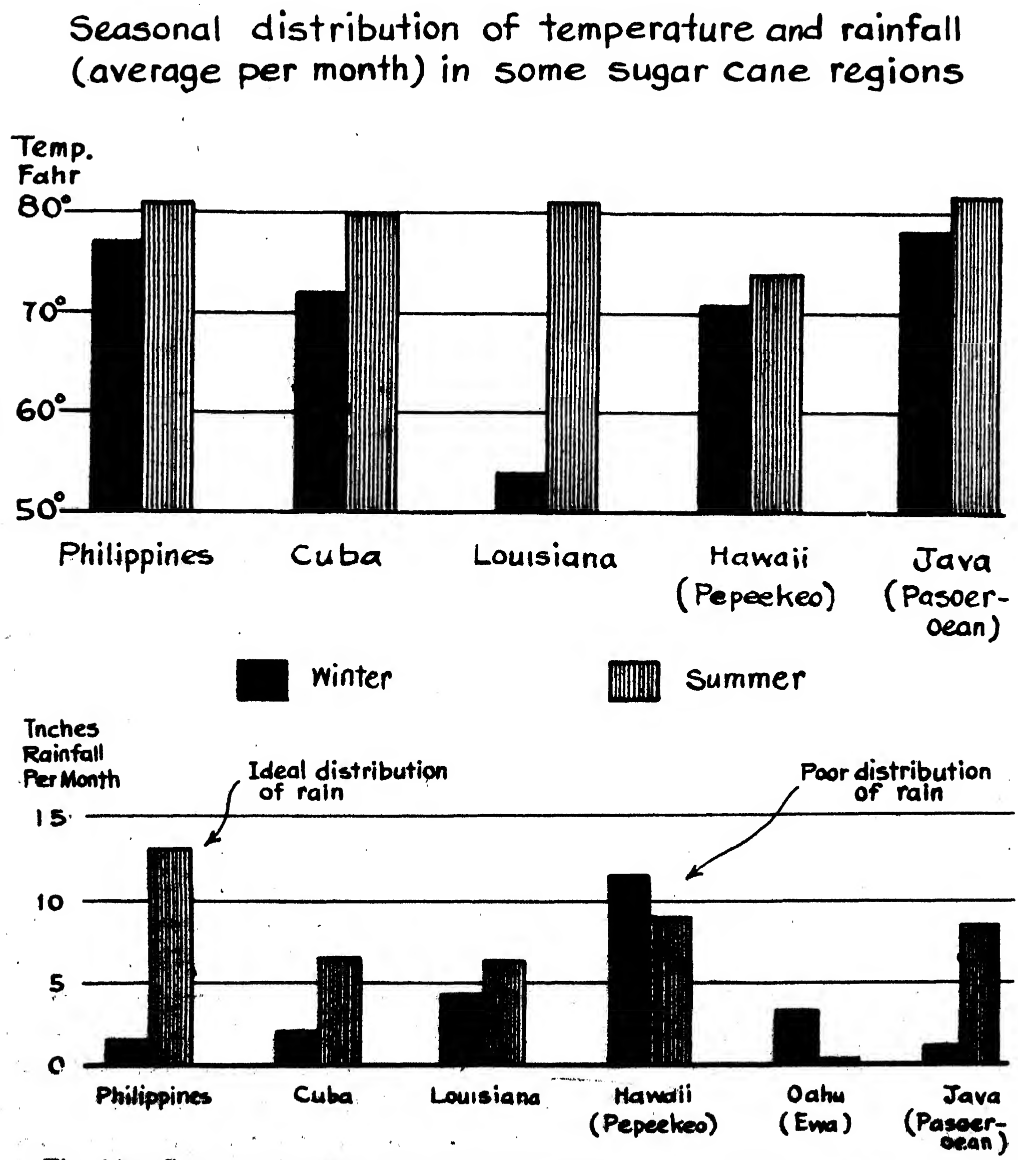


Fig. 1A. Compare the wet summer and dry winter of the Philippines as against the dry summer and wet winter of Hawaii.

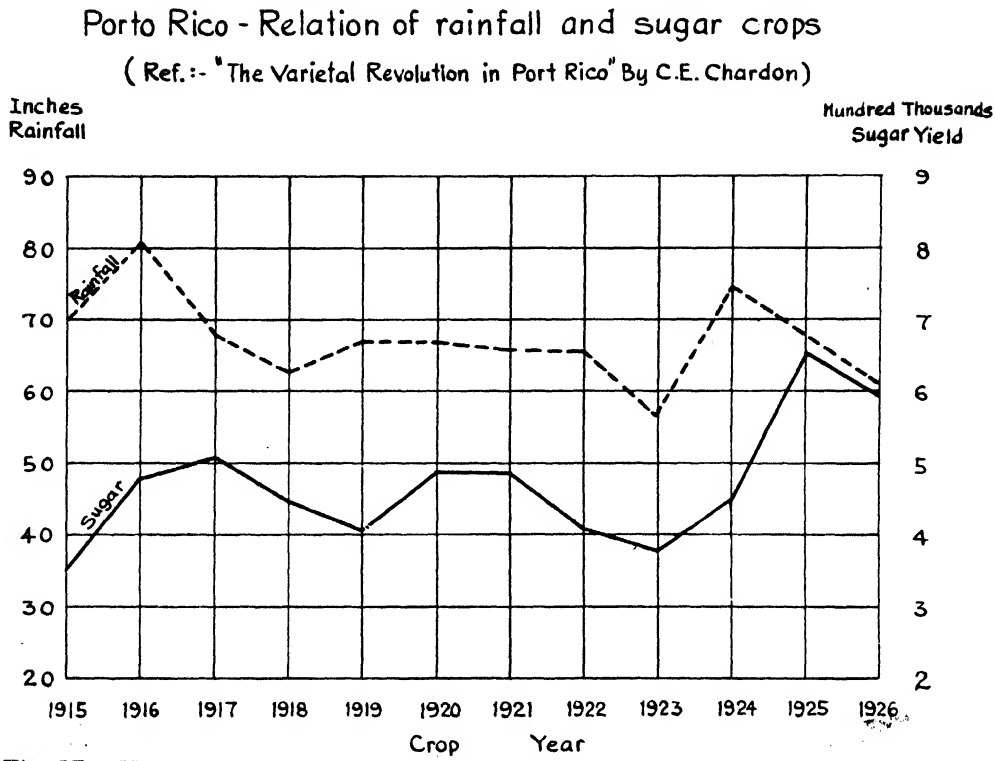


Fig. 1B. Note the close correlation between rainfall and sugar yield in Porto Rico.

What we need, therefore, is to organize our knowledge of the influence of weather on sugar cane, so that not only shall we be able to put down losses to bad weather but also we shall be able to estimate the increased yields due to good weather.

How do these weather conditions affect a crop of sugar cane? First, let us see what we need to grow a successful crop. We need (1) time, (2) light, (3) warmth, (4) moisture, in the soil and in the air, (5) plant food. Of these we can control time and plant food and we can partially control, or better, we can supplement the deficiency of moisture, at least on irrigated areas. Of the other factors, over which we have no control, we may have enough or not enough for our crop.

Sugar cane is a tropical plant and it requires plenty of moisture and warmth for good growth. We know, for instance, that cane grows so much more in summer than in winter, that is, the increased temperature and light in summer increases the rate of growth. We also know that cane suffers if there is not enough moisture in the soil, especially in summer when the rate of growth is higher. To obtain a good crop we should; therefore, have light, warmth, moisture, etc., and each at the right time and in the right quantity. That is just where the weather affects us. Though it is true that the average temperature or average rainfall from year to year may not show great fluctuations, the seasonal temperature and rainfall may. That is, one year we may have a very hot summer and little rain, another year a cool summer and too much rain, and still another when we have both high temperature and high rainfall. We can easily see then, that in the last case growing conditions would be ideal and as a result we would expect to harvest a bigger crop.

A good deal of work has been done in recent years both here and abroad in organizing such loose observations and systematizing the relationship between weather conditions and crop yield. Here, we have studied the annual fluctuation in the yield from year to year in the case of an unirrigated plantation, the Pepeekeo Sugar Co. and an irrigated plantation, the Ewa Plantation Co. We know that the tremendous variations in the yield from one year to another could not possibly be due to anything that we could or could not have done, for our methods and cultural practices do not change so abruptly from year to year. True we may have two tons more sugar per acre in 1925 as compared with 1910 because of improved methods, but there is no reason why we should have a ton more sugar in 1915 than in 1913, 1914, 1916 or 1917. These big variations, we can reasonably believe, were brought about by factors beyond our control.

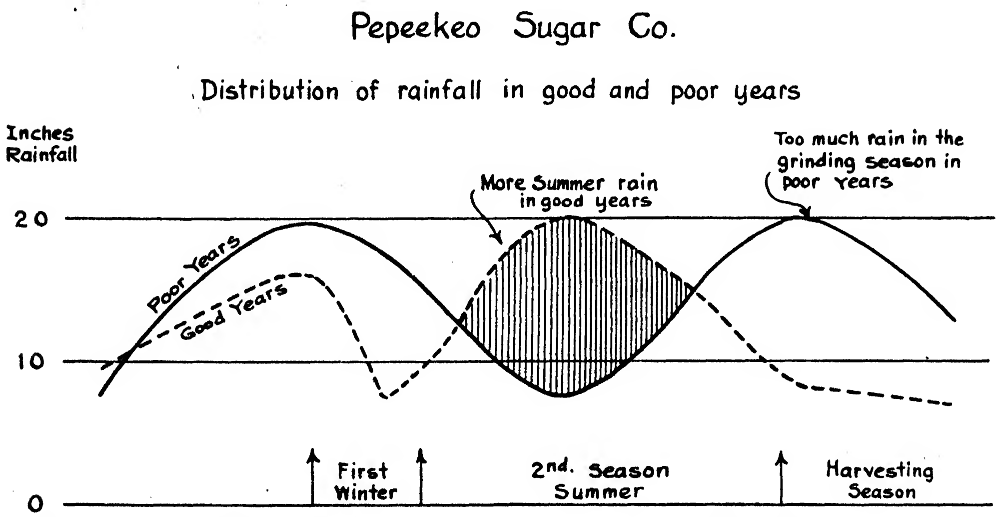


Fig. 2. Rainfall was ideally distributed in the case of high yield years; poor crops were harvested when rainfall was insufficient in the growing season and overabundant in the harvesting period.

In the case of Pepeekeo, we picked out some years that showed a big increase in yield and also some that showed a big decrease compared with the neighboring years. We then started to find out the average condition of warmth and also moisture for the good and the bad years. From Fig. 2, we see that the good years had the right amount of water in the right season, that is, more water in the summer when the cane is growing vigorously and less water in the harvesting period when the canes need to be ripened. From Fig. 3, we see that both in the first season, and second season, the good years had more warmth than the bad years. In other words, what we had often suspected to be the cause of our decreased yields, is found on analysis to be entirely correct. In such years we had drought when we needed water and too much rain when we wanted to ripen our cane and did not need any. The same holds true, more or less, in the case of the irrigated plantation we have studied, with the only difference that in this case the quantity of irrigation water, not so much rainfall, is the important factor.

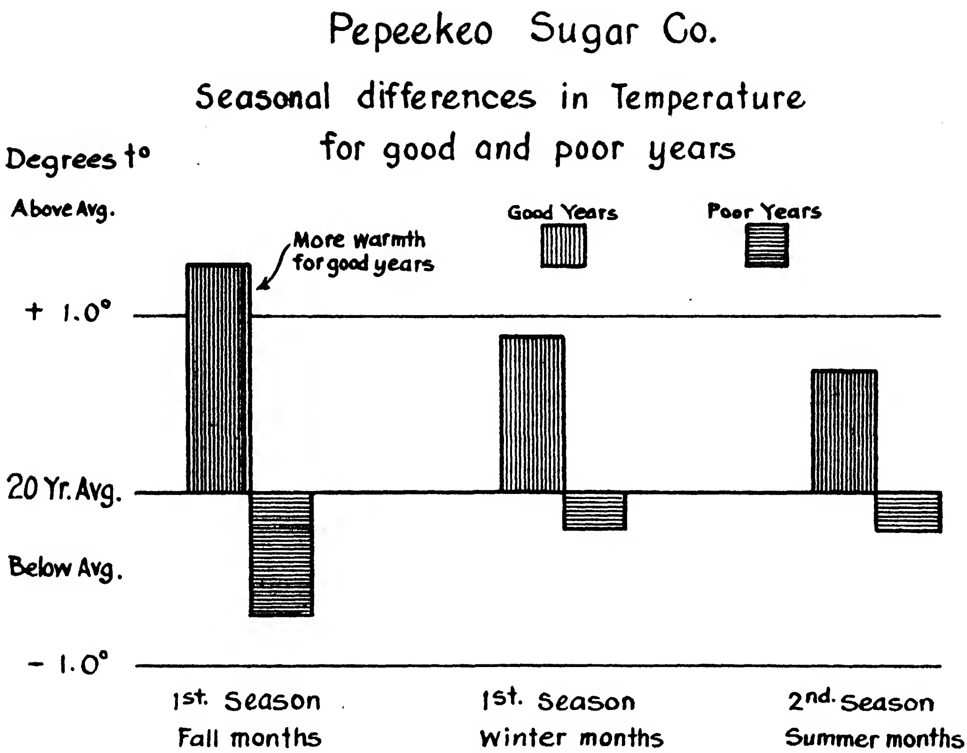


Fig. 3. Warm growing weather reflects itself in higher yields. Temperature was consistently above normal in the high yield years and consistently below normal in the poor years.

Total Warmth and Sugar Yield at Pepeekeo

In the case of Pepeekeo (and what we have to say of Pepeekeo holds true of the island of Hawaii as a whole) we also made another significant discovery, that our periods of high yield and low yield showed a definite relationship to conditions of warmth. It is easy to visualize and gauge the efficacy of one inch of rainfall but not so one degree of temperature. One week we have a temperature of 78° and the next, perhaps 79°. Most of us would not notice the difference, if we were not told so; but the plants being more sensitive know the difference right away and they respond to such differences and it really makes a big difference in the growth of a plant. Let us figure it out this way. We know cane does not make any growth in Louisiana in winter when the mean temperature is 55° F. That means that in the case of sugar cane, only a temperature of over 55° is effective. A temperature of 78° means 23° of effective temperature, and 79° is 24° effective. That gives us a relation of 23 to 24 or 100 to 104. If sugar cane grew exactly in proportion to the warmth it receives, (and there are evidences that it does so to an extent) then, as a result of this one degree difference, and other things being equal, we would expect to get a 4 per cent better growth. Most probably, the actual difference would be greater because we have reasons to believe that the lower limit of growth is not 55°, very likely it is over 60°. However, what we started to make out is that an imperceptible difference in warmth may make an appreciable difference in cane growth. Now if we collect for every

Pepeekeo Sugar Co.

Annual variations in sugar yields compared with variations in the conditions of warmth.

(Unit of warmth = 1 degree mean t° above 60° F for one day)

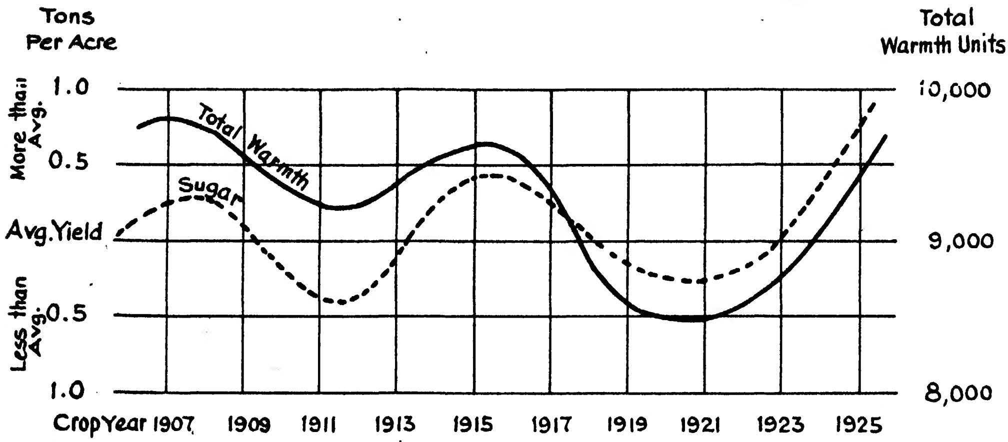


Fig. 4. The periods of low and high yield at Pepeekeo coincide with periods of low and high temperature. Temperature above the average is, therefore, essential to high production.

crop year, all such degrees of temperature above 60°, and also count the number of days when these differences obtained, we find, what we may call, the total quantity of effective warmth for any given year.

In Fig. 4, we have charted the total warmth thus calculated against the sugar yield of the corresponding year. We have used free hand curves just to show the tendencies; the individual years do not always show corresponding fluctuations due no doubt to the influence of other factors such as moisture, plant food, etc. Fig. 4 shows that the periods of high and low yields are definitely associated with conditions of warmth. We are growing a tropical plant in a subtropical climate and it should not, therefore, surprise us to find that warmth has such a big influence. It does not mean that other factors such as our methods and cultural practices are of no importance, it means only that together with others, the condition of warmth is also a factor in production that should be reckoned with.

Weather Conditions and Juices

Our knowledge of the influence of weather conditions on the physiological processes of cane ripening is still meager. In general, we may safely assume that whatever affects the processes of growth also affects the processes of ripening—though the effect may not be of the same nature or degree. Recent studies indicate that good juices are generally obtained when the days are bright and warm and the nights cool during the growing period of the crop and particularly in the fall months before harvest. Excessive rainfall during or immediately preceding harvest is detrimental.

Fig. 5 shows graphically what we believe to be the effect of moisture and warmth during and immediately preceding harvesting seasons. But it must be

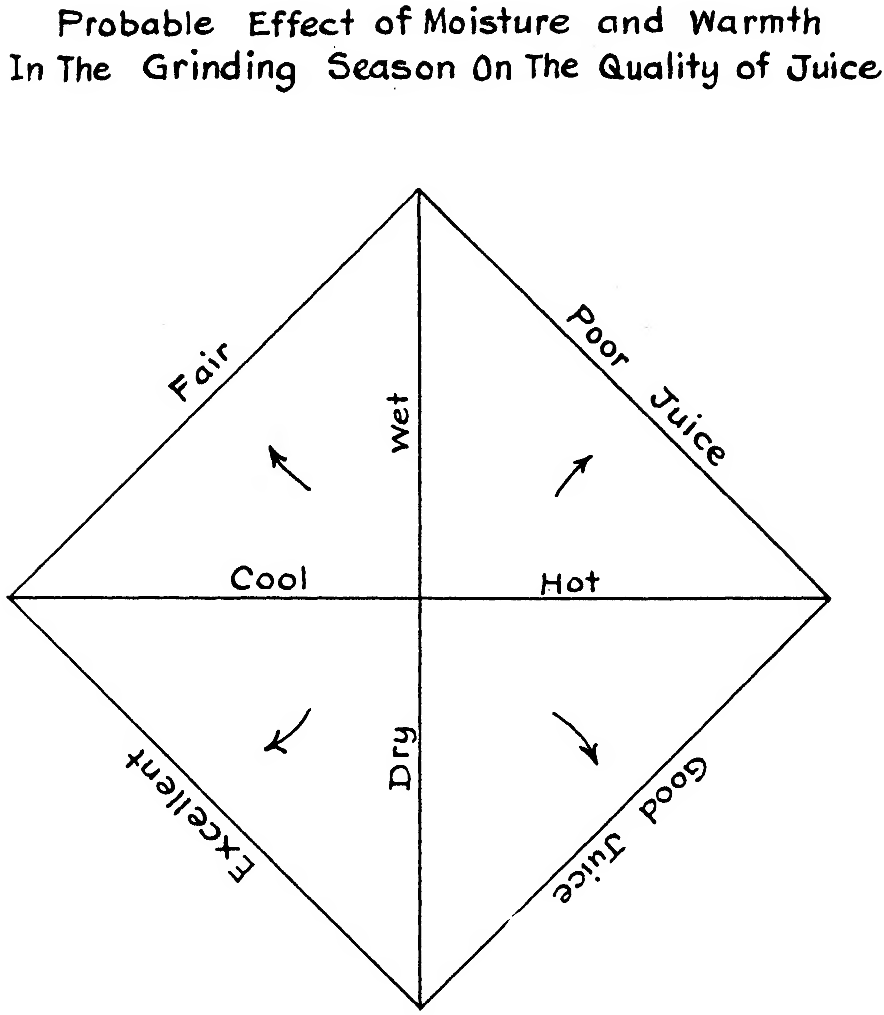


Fig. 5. The above is only a part of the picture. Weather in the grinding season alone does not determine the quality of juice. The conditions of the growing season also have influence.

borne in mind that conditions during the grinding season alone cannot account for the good or poor juices; the conditions of weather and field culture under which a crop is grown have as much, if not greater, effect on the quality of juice.

Weather and Sugar Yield in Other Countries

The same kind of relationship between warmth, moisture and sugar yield has been found to exist in Java, Mauritius, Philippines and Louisiana. Everywhere, it has been discovered that it is not so much the annual amount of warmth or rainfall that counts but the seasonal amount and more precisely the quantity of warmth and moisture that a sugar cane crop receives at a particular period of its growth. These periods have been called the critical periods and it has been shown that if the plants do not have the optimum requirements at these critical periods they are checked permanently. In these islands also, we have such periods and

most of the plantation men have some ideas about these; but we need to know them more definitely so as to be able to follow the progress of a crop more closely.

Conclusion

Summarizing, we can say, climate is of great importance; firstly, it makes a country a good or a bad sugar cane country, and secondly, its temporary phases, otherwise called the weather, materially influence our yields from year to year.

All over the world, we have just begun this absorbing study of the relation of climate to sugar production. We need to know more, and more definitely about the influence of such factors on growth as sunlight, maximum and minimum temperature, humidity, etc. The preliminary studies have already given us a better knowledge of the relationships which we had often suspected but could not always prove.

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The Significance of Climatic Differences Among the Sugar Plantations of Hawaii

By U. K. Das

In comparing one plantation with another, we usually take into consideration the differences in soil types and in the amount of rainfall, or of water supply if they are irrigated plantations; but hardly ever do we give much thought to the differences in the climatic conditions of the two places. This is perhaps the result of a belief that climatic conditions cannot vary to any extent within the narrow geographical limits of these Islands. Our belief is far from being well founded; for recent studies of the relation of weather to sugar production of these Islands have shown that imperceptible though the climatic changes are to us human beings, they are nevertheless reflected in the yield of sugar cane crops. The accompanying chart appears to suggest that the climate of our sugar plantations is of greater significance than we have hitherto credited it with.

Climate and Variety Distribution

It is generally recognized that climate, particularly temperature, is the most important factor in the distribution of crops. In these Islands, we talk of good H 109 districts, good Yellow Caledonia districts, etc., implying, thereby, that there are certain localities eminently suited, by virtue of their climate, to grow H 109 or Yellow Caledonia. This chart lends general support and gives a broad definition to the view thus expressed.

If we locate the plantations where H 109 grows well, we will see that they fall within certain well defined limits. Good H 109 plantations have an annual maximum temperature of over 82°, a range of temperature of over 16°, and rainfall of less than 25 inches a year, and they are all irrigated plantations. A good H 109 district is, therefore, one with high maximum temperature, fairly high range of temperature, and ample, well distributed water.

All the typical Yellow Caledonia plantations are, on the other hand, located below 80° maximum temperature, have a range of 14-16°, an annual rainfall of over 75 inches and are all unirrigated.

In the area between these two climatic districts, one of H 109 and the other of Yellow Caledonia, we encounter plantations some of which lean towards H 109 and others towards Yellow Caledonia. These plantations between 80° and 82° are perhaps in an undefined territory not knowing where they belong. These are often the places looking for some new variety that will just fit in.

Climate and Juice Quality

In our recent studies of weather and the quality of juice at Ewa (*Hawaiian Planters' Record,* Vol. XXXV), it has been shown that range of temperature has a great influence on the quality of juice. Within certain limits, a high range is

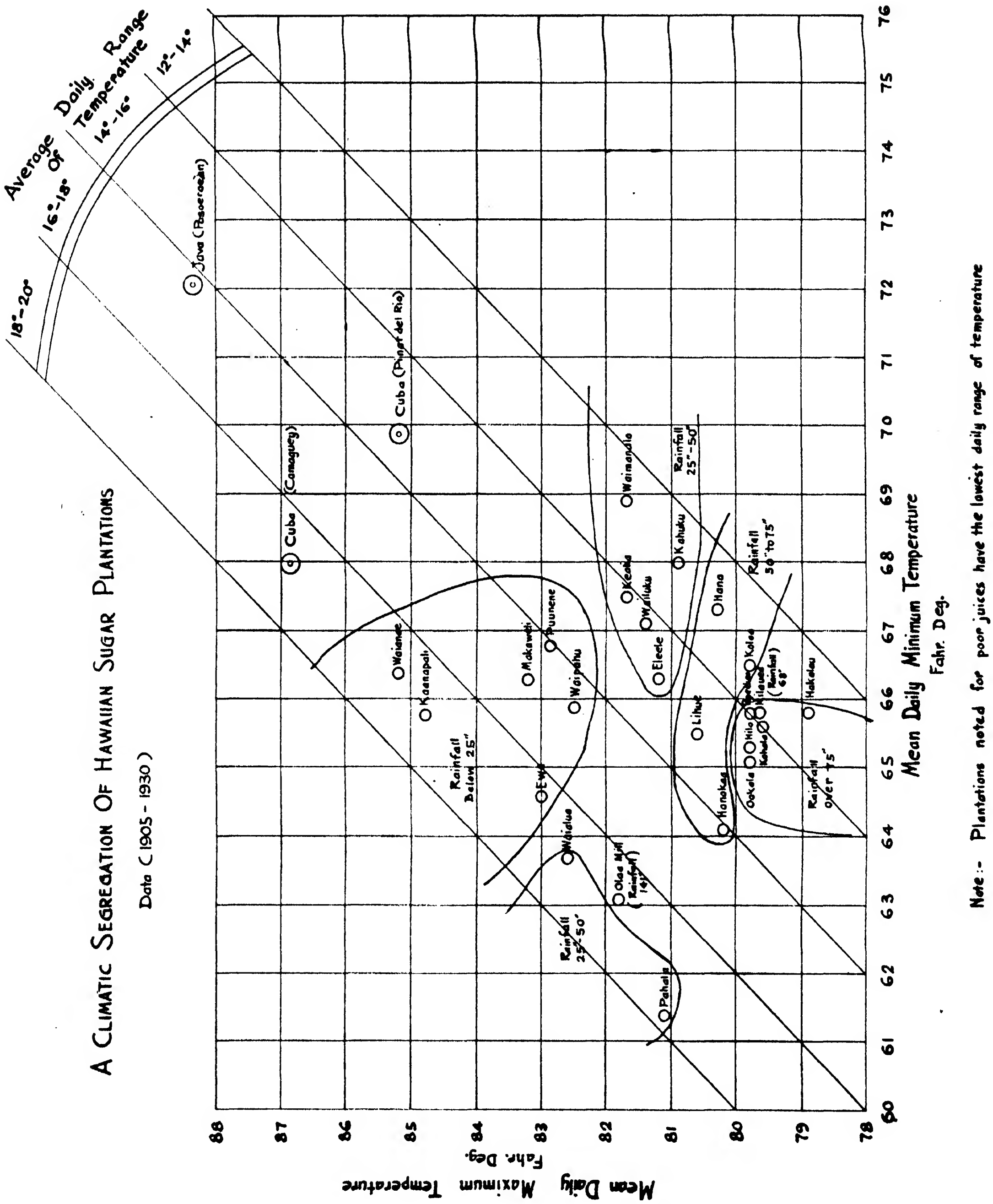
Explanation of Chart

This chart gives information on four points: (1) the daily mean maximum temperature, (2) the daily mean minimum temperature, (3) the mean daily range temperature (range=difference between maximum and minimum temperature), (4) the total annual rainfall. Each plantation is located on the chart by its maximum and minimum temperatures. Thus Pahala is seen to have an annual maximum temperature of 81.1° and an annual minimum of 61.4°; Ewa a maximum of 83° and minimum of 64.6°. Diagonal lines are drawn through points having the same difference between maximum and minimum temperature. These are the lines of equal range of temperature. For the sake of simplicity these lines have been placed two degrees apart, giving ranges of 12-14°, 14-16°, etc. Now, when we look at a point on the chart, say Ewa, we may see that it has an annual mean maximum temperature of 83°, an annual mean minimum temperature of 64.6°, and it has a mean daily range of temperature of 18-20°, or 18.4 to be exact.

The plantations are further grouped according to total annual rainfall. Again for the sake of simplicity the divisions are from 0-25 inches, 25-50 inches, etc. A free hand curve is drawn around plantations belonging to the same rainfall group. The chart is now complete and from it we read that Ewa Mill has an annual mean maximum temperature of 83°, an annual mean minimum temperature of 64.6°, an annual daily range of temperature of 18-20°, and it has a total rainfall of less than 25 inches a year.

On this chart as we go from the bottom upwards, the maximum temperature increases; as we move from the left to the right, the minimum temperature gets higher and higher, and as we move from the right to the left diagonally across the chart, we encounter plantations having greater ranges of temperature.

Java and Cuba have been located on the same chart, for the sake of comparison. Attention is drawn to the great differences in temperature between the plantations of these Islands, and also between Java, Cuba and this Territory as a whole.


A Climatic Segregation of Hawaiian Sugar Plantations
Data (1905 - 1930)
Average Daily Range of Temperature
18°-20°
16°-18°
14°-16°
12°-14°
Mean Daily Minimum Temperature
Fahr. Deg.
Mean Daily Maximum Temperature
Fahr. Deg.
Java (Pasoeroean)
Cuba (Pinar del Rio)
Cuba (Camaguey)
Cuba
Rainfall Below 25"
Rainfall 25"-50"
Rainfall 50" to 75"
Rainfall over 75"
Waianae
Kaanapali
Makaweli
Puunene
Waipahu
Ewa
Waialua
Olaa Mill (Rainfall 141")
Pahala
Waimanalo
Keaha
Wailuku
Eleele
Kahuku
Hana
Lihue
Hanakaa
Ookala
Hilo
Kohala
Kolea
Hakalau
Note:- Plantations noted for poor juices have the lowest daily range of temperature

generally favorable and a low range detrimental. (High range of temperature is usually obtained when the days are bright and clear and the nights cool. High range of temperature, therefore, signifies ideal conditions for the elaboration and storage of sucrose.)

The chart lends general support to our previous findings.

Within the belt of lowest range, namely 12-14° on this chart, we find plantations like Kahuku, Waimanalo, Kaeleku, Kilauea, all of which have generally poor juices. As we move diagonally towards the left, the temperature range increases and we encounter places that generally yield cane of good quality.

Windward and Leeward Plantations

As the rainfall and temperature of these Islands are mainly influenced by the prevailing trade wind, it is to be expected that our windward plantations will have more rainfall, lower temperatures and less range of temperature. Thus in the right, lower end of the chart are located most of our windward plantations. The leeward sides of our Islands thus appear to be better for cane growing, provided there is a plentiful water supply for irrigation.

Comparative Study of Plantations

Heretofore, plantations have been compared as to efficiency, cost of production, etc., sometimes without regard to the natural climatic limitations of the places. This chart will show that in any such comparison the natural advantages and disadvantages of the climate should be taken into consideration. Unless we allow for the influences of climate, it would be unfair to compare plantations widely separated on this chart.

Remarks

This chart is purely suggestive and only broad conclusions can be drawn from its study. The reason for this, is the fact that the climatic data recorded by one weather station may not be representative of the whole plantation, and secondly there are other local factors such as exposure, sunshine, etc., which are also of significance. As more data on the climatic conditions become available, a chart of this nature will become of increasing value. In the meantime, it is hoped that this chart will arouse more interest in recording and studying the various climatic factors that affect our sugar cane crops.

Field Experiment Technique*

By Ralph J. Borden

THE TYPE OF PROBLEM

The plantation management is confronted with a mass of problems that the field experiment can help him to solve. It would be quite simple to list twenty-five or thirty of such. It is quite improbable that any plantation is in a position to tackle many issues at any one time since the amount of land, effort and money that can be devoted to field testing is limited. In order, therefore, to determine those problems that can best be decided without an experiment and those which are most vital at the time, a thorough analysis of the situation by one who is competent and fitted to judge the issues involved, is highly desirable.

Every plantation has its more or less well-established varieties, fertilizer practices, and cultural methods. Changes in these will only be considered when some permanent advantage will accrue the stockholders; hence there must be a possibility of econonic gain or detection of loss before the installation of a field test can be sanctioned.

If the results of a field experiment can be applied to two or three thousand acres of the plantation, we must give such a test precedence over one from which the results can be absorbed and put into practice on only two hundred acres. A possibility of increasing sugar yields by one-half ton of sugar per acre on 2300 acres might well represent an increased income of $50,000, for which an expenditure of a few hundred dollars for a field test would have ample justification. On the other hand, if the experimental results were applicable to only a relatively few acres, then our best judgment should supersede an attempt to test the issue in the field.

When deciding which issues should be tackled first, recognition should be given to the greatest limiting factor of profit from crop yields. If water is the limiting factor, then irrigation experiments are imminent; if the variety of crop cane being grown is giving unsatisfactory returns, then variety tests should get first consideration.

In deciding which plant food issues to test in the field, it is essential that data secured from a thorough soil survey, and from analyses of cane and mill products be available. From these data, one who is well grounded in the many phases of soil sampling and analysis, and the allied subject of analysis of cane and mill products, can intelligently plan tests for the special conditions existing.

No matter what the issue: fertilizer, variety, irrigation or cultural practice, it must be viewed in the light of its possible adaptability to field testing and to its practical value to the plantation. If the results are sound, the practice should be one that can be absorbed and put into effect with corresponding gains and economies to the plantation management.

* Submitted at the ninth annual meeting of the Association of Hawaiian Sugar Technologists, October, 1930, with the endorsement of the Committee on the Technique of Conducting Field Experiments.

THE PLAN (TO REDUCE ERRORS)

Progress in any endeavor is built on an analysis of past experience. Modern methods of interpreting the results of our older field experiments have shown that variations and errors of observation have sometimes caused us to draw conclusions which were not justified from the amount of data that was available. Such experiments, however, have had their value in giving us a keener realization of the limits of field testing and the necessity for more exact methods. Twenty-five years ago the application of an additional 50 pounds of nitrogen per crop gave a response to our half-starved cane that was visible to the eye, and easily measured in gains of sugar per acre. Results from more recent experiments have shown that 50-pound differences often give no significant response on our better fed crops. Therefore, it becomes necessary to use greater accuracy and more refinement in our experimental methods and to so plan our tests that its unavoidable error will be minimized and its results not misleading.

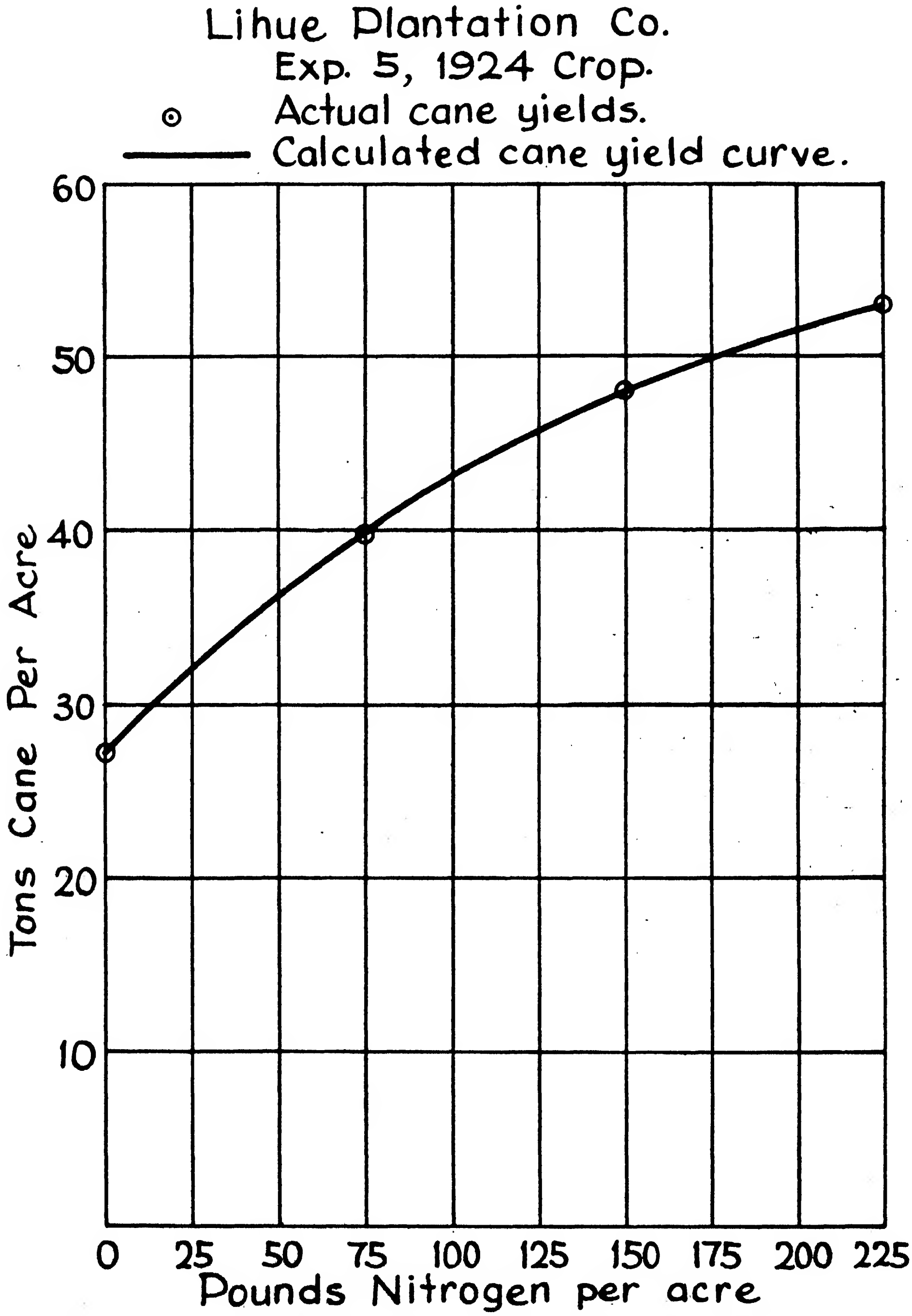
Starving cane (at left) showed clear cut response to food it was able to secure from the adjacent nitrogen-fertilized rows (at right).

The Number of Subjects:

Realization of the many independent factors which affect a living crop at every stage of its development, and knowledge of the variations which may exist in our soils make it necessary that we confine ourselves generally to only one or at the most to two closely related subjects in any individual test in a cane field. If information is desired concerning other factors, it is best to make a separate study in another test which is especially designed.

THE VARIATES OR TREATMENTS:

Simplicity should be the basis of the field experiment. The deliberately introduced variables, should be few; seldom more than four, unless every third plot is a control or check plot. With variety tests, two or three variates make it possible for our comparisons to be made on adjacent plots, and we thus get the closest to actual similarity of environments that is possible. With fertilizer tests in which



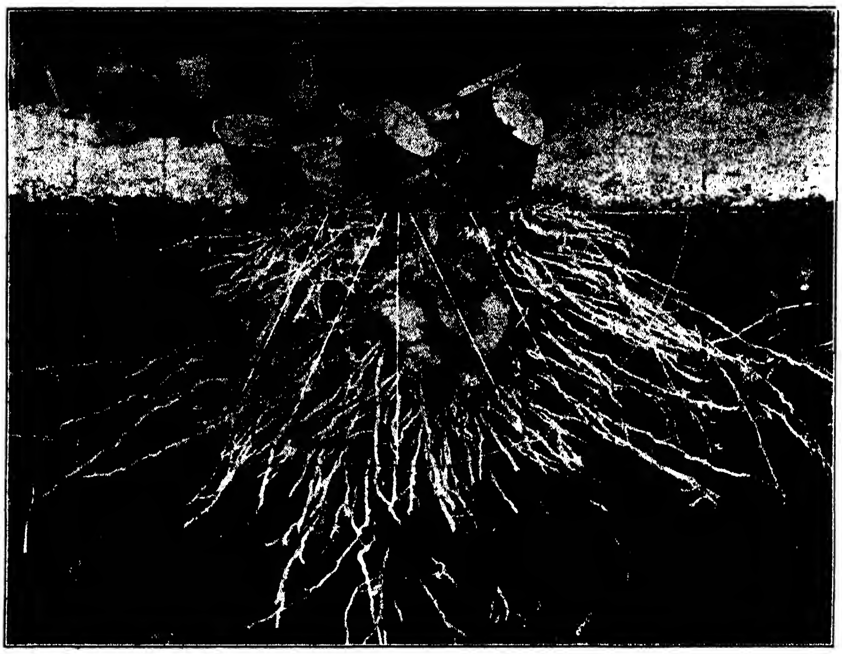
Curve constructed from results of field experiment that carried four varieties.

optimum amounts are to be sought, at least three variates are necessary (four are preferred), in order to construct a curve from the results, so that the effect of intermediate amounts can be interpolated. For such tests, until the rougher amounts have been determined, the differences between the variables should be quite large: 75 pounds for nitrogen, 100 pounds each for phosphoric acid and potash; the mid-point being the general plantation practice.

SELECTION OF THE AREA:

History:

The most important consideration in connection with the selection of an area for the field experiment is that we know something about the variations which exist within and upon our proposed experimental area, and realize how these variations may affect our results.



The location of the cane root system makes it imperative that we know something of the conditions *within* the soil mass, as well as the visible knowledge we can more easily secure from an inspection of the surface area.

On many plantations the field men can tell us much about the past history and performance of their fields. We should attempt to choose a uniform area with average fertility which is representative of the section for which the results are desired. Neither the poorest nor the most fertile spots are suitable. Areas that have carried a former field experiment or been used for seedling tests, that have had a different cropping program, been partly fallowed or pastured, received different kinds of preparation or planting, ~~or~~ upon which the application of fertilizers, soil amendments or plantation by-products has not been uniform should be avoided because of the residual effects that may be apparent in them for many years. Sections that are considered vulnerable points for disease or insect infesta-

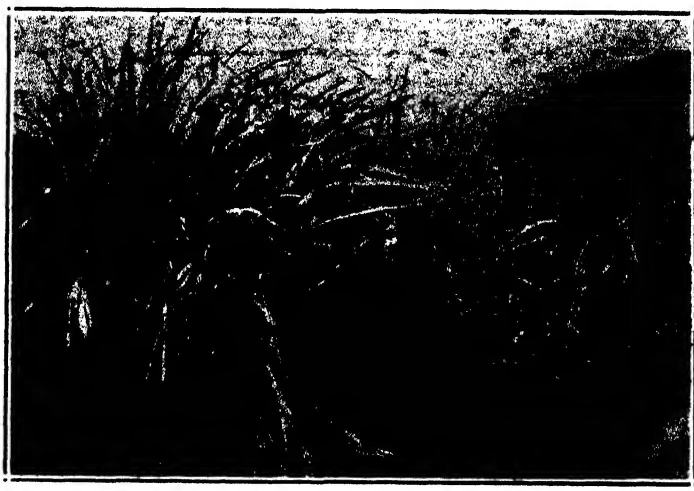
tion, or which are likely to be altered during heavy rains, are best avoided, so that with tests once installed, we may have better assurance of comparable crops to harvest.

Inspection:

Evidence of the suitability of a particular area for the specific location of our field experiment is generally found by an inspection of the topography. Quickly changing contours and steep slopes are best avoided, as also are areas where there is visible evidence of uneven top soil depth, and of spot variation which may be due to any number of causes: drainage, rocks, trees, exposure.

Inspection of cane on the ground at the time of a previous harvest will often reveal areas that are not suitable for comparative plot studies.

If the test is to be installed after the stand of cane is well up, an inspection of the cane growth at two to three months will greatly assist in locating our plots where the results will be comparable.



Cane affected by Pahala blight. Familiarity with the history of the field will forestall the inclusion of such a susceptible area within the experiment.

Soil Analyses:

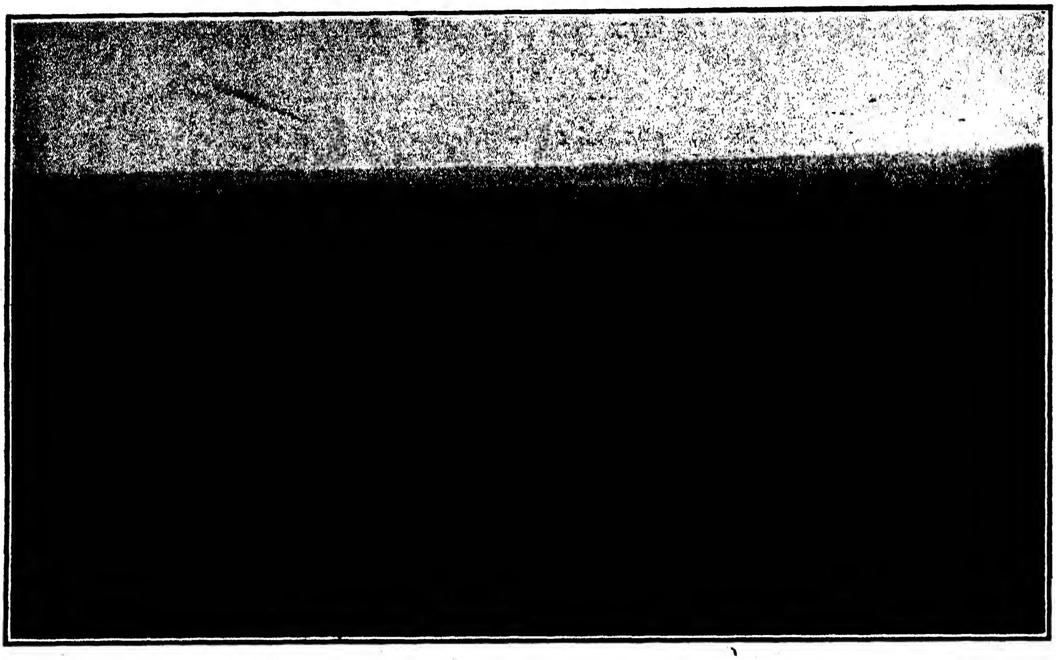
Soil analyses, as a guide to the placement of our field tests, are often helpful. Nullified results have been obtained from fertilizer experiments which soil analysis data would have warned against installing. Varieties may have been tested at a disadvantage on soils with an insufficient mineral food supply.

Convenience:

In selecting the area, a spot is desirable that is easily accessible to those who will contact the experiment, and that will present no barrier to the regular plantation routine, particularly at harvest time. Located where it can be frequently seen, without effort, it should do much to interest the plantation people and secure their cooperation.

Permanence:

A one-crop experiment rarely allows one to draw definite conclusions. The experiment must be continued several times before changes based on its results can be recommended. Hence, in selecting the area, we must locate with this question of time in mind, and use a spot which will be available for the proposed life of the test.



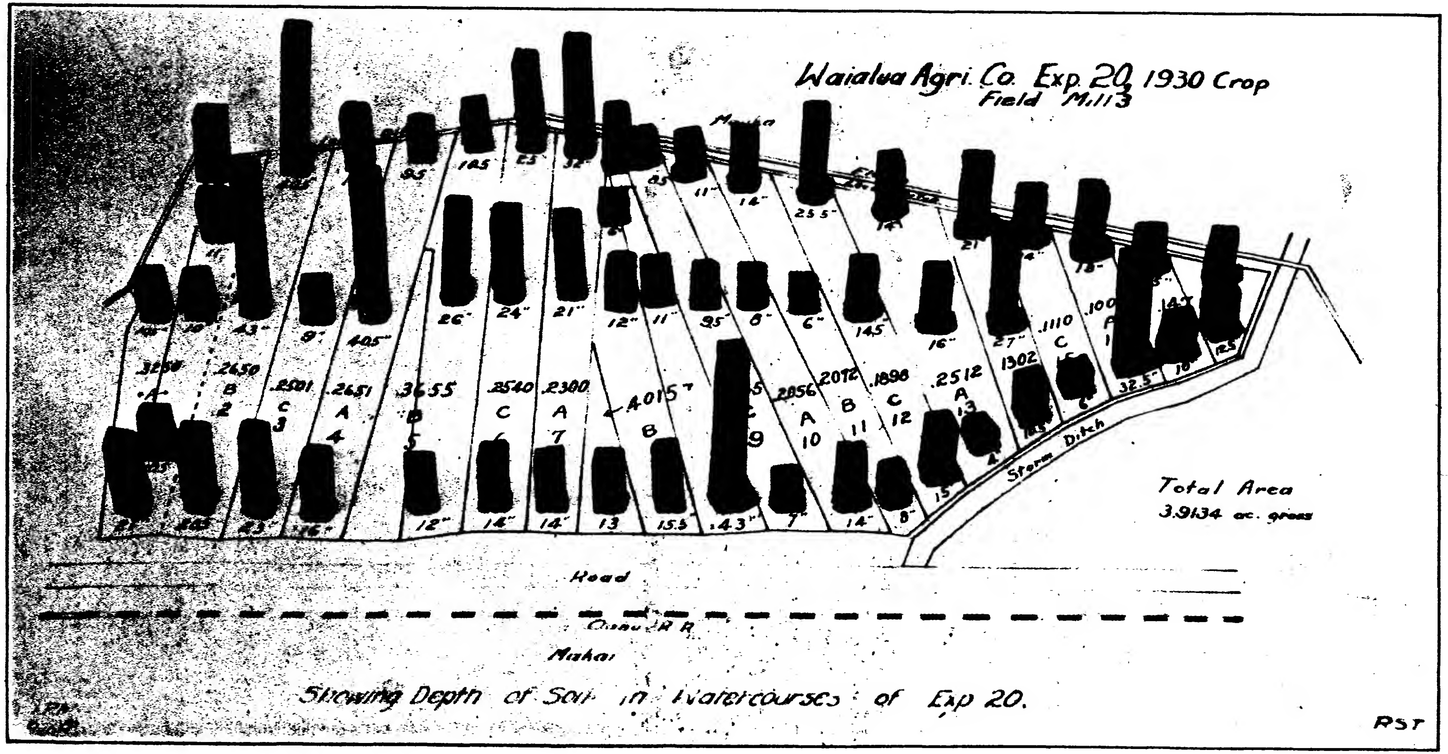
A 100 per cent germination or a full stand of cane will start all plots off on an equal footing.

Low Plot Variation:

The most important consideration in selecting the specific area for our field test is to locate it where there is the greatest probability of having only slight variations among the plots. Differences in natural soil fertility are hard to detect unless crop response to such differences is measured. Differences in soil depth and texture may be avoided through inspection of soil borings taken thruout the proposed area.

One indication of the suitability of an area for field experiments may be found in an analysis of data from tests which have been conducted in the particular field where we wish to install our layout. If former tests there show evidence of extreme variability, their general location should be avoided. On the other hand, if there is evidence of a considerable amount of similarity, the degree of such will tell us whether we can locate in close proximity to former test areas and significantly measure small differences from various treatments given.

The inherent variations in fertility that exist in specific areas can often be found from the results of a uniformly treated crop previously grown thereon. When such results are plotted, the extent and direction of the general fertility slope and the outstanding evidences of spot variation are quite apparent. The



Such differences in soil depth are apt to cause yield fluctuations greater than would be expected from surface observation.

general suitability of such area for the problem to be tested may be indicated. Especially when the test is to be first installed on ratoon cane may a plot by plot harvest of the area in the preceding crop indicate whether we have picked a suitable spot for our particular test. For those plantations that may be planning a field test program for fertilizer control the securing of yield data from several uniformly treated possible test areas in all large fields will be exceedingly valuable in determining the suitability of the area for the problem to be tested, and in devising plans to significantly measure the yield responses that may be expected in their testing program.

PLOT DESIGNS:

The design of our field experiments is largely a matter of convenience, yet there are some factors connected therewith which it is essential to have in mind if we are to increase accuracy, reduce error and get results in which we can place confidence.

Size:

The nature of the problem, the extent of suitable land available, the field practices being used, and the degree of soil variation will all have to be considered before we can decide that size of plot which will allow for the most accurate comparisons for our test.

Smaller plots have an advantage over large plots in sections where the soil variations are wide, but the smaller number of plants they carry makes them more subject to variations in stand and errors at harvest. Although large plots are not as reliable as small plots where the soil conditions are variable, the use of a Blank Test should make it possible to locate large plots with due regard to the existent inherent fertility. If there is any possibility that the necessity for accuracy will be lost sight of, or that the number of replications will be cut down, when large plots are to be used, these factors would tend to offset any advantage to be gained by using the bigger plot size.

From a study of our local conditions, the following plot sizes are recommended:

Maximum:	Doubtful if any maximum size can be set. This will depend upon the problem, the harvesting facilities and the suitability and size of the field for an adequate layout.
Minimum:	For irrigated cane, machine loaded: 2 watercourses.
Minimum:	For irrigated cane, hand loaded: 1 watercourse.
Minimum:	For irrigated cane, flume loaded: 2 watercourses in each of 2 level ditches.
Minimum:	For non-irrigated cane, wagons: 1/10 acre.
Minimum:	For non-irrigated cane, flume or rope: 1/20 acre.

Shape:

The question of shape of plots for cane experiments is very closely tied up with the matter of size. On the irrigated lands, convenience will probably determine the shape, and we will use the watercourse plot: single, doubled or multiple.

On the unirrigated area, we should be able to take advantage of the best experimental technique. There is much to be said in favor of the long, narrow plot, with its long axis laid in the direction of the greatest soil variation, for this brings the plots closest together and assists in reducing the error due to plot location. In this plan, however, it is not desirable to have less than six rows (eight would be preferable) for it will be necessary to discard the outside rows of each plot, in order to eliminate any border effect.

Replications:

The value of replication in a field experiment is in the significance it gives to the results. By repeating a treatment several times, allowance is made for most of the variations which affect results and the magnitude of errors made in conducting the test and at harvest are distributed, so that their effect upon any one particular group of plots is negligible.

No treatment, repeated in a field test, will give exactly the same result twice. The degree by which the results differ, give us our assurance of their reliability. For instance, if we measure an increase of 10 tons of cane from an extra application of potash on one plot, we have no assurance that we can get this gain again by a similar treatment. If a second plot, similarly treated gives us 9.4 tons of cane extra, we would have a little more confidence in our tonnage gain, and if 5 more plots gave us a gain of 9.6, 10.1, 9.4, 9.0 and 9.8 tons, we would be warranted in placing considerable confidence in the average gain secured. However, if the second and third plots gave us losses, and the other 4 plots showed gains of 1.1, 2.5, 6.8 and .5 tons, we would have no assurance therefrom that the extra dose of potash would actually increase our yields. Naturally therefore, *other things being equal,* the more replications we have for comparison, the greater will be the confidence that we can put in the results secured.

The number of replications to include is largely a local problem and will be determined by the following factors:

(1) The unavoidable errors of our field experiments.

(2) The degree of accuracy which can be applied to reduce the avoidable errors.

(3) The degree of difference in results which we desire to measure.

A study of the errors of Blank Tests harvested from commercial cane fields in 1929, as well as from some 450 field tests harvested throughout the Islands during the last 10 years, seems to show that we will need at least 7 replications to measure an expected difference of 10 per cent in cane yields, and that 20 replications could only measure to a 6 per cent difference. However, with the greater accuracy which can be given to field experiments, it has been pointed out by Manager E. W. Greene, of Oahu Sugar Company, Ltd., that from 6 to 10 replications can be made to significantly measure an expected difference of even 5 per cent.

On this basis, it is recommended that all field tests carry at least 10 replications, in order that we may be able to significantly measure the increasingly smaller differences which we shall have to be prepared to detect in our future field investigations.

Arrangement of Plots:

The arrangement of plots in a field test should be such as will make possible a comparison of yields from closely adjacent areas to which different treatments have been applied. Soil variation exists and will influence the results of any test, but by using an intelligent arrangement of plots we can do much to minimize its effects. Hence, the probability that the soil conditions of adjacent plots are apt to be quite similar, makes that layout which provides for comparisons of closely adjacent plots, the best we can have.

Guiding Principles: Naturally, it is realized that one cannot lay down any one "best" arrangement for experimental plots. Hence, the following principles are enumerated as a guide in the selection of a preferred layout:

(1). Keep plots which are to be compared close together; adjacent if possible.

(2). Where a "Blank Test" precedes the experiment, the location of the different units of the series of treatments may often be established from the information obtained therefrom. Plots can be so arranged that each treatment includes portions of the area which have shown a high, medium and low degree of fertility.

(3). Where the suitable area is unlimited, the checkerboard layout will give the most reliable results, and its use will make a preliminary blank test unnecessary.

(4). Where the desired area is limited, and the soil fertility slope unknown, the Latin Square arrangement will keep the plots close together and afford a means of determining the extent of the random variation.

(5). Unless the soil variation within a level ditch area is known to be a minimum, it is preferable to select an arrangement of plots so that their total area will approach a square, rather than to spread the plots out in a long narrow strip throughout one level.

(6). For direct plot-to-plot comparisons, the long sides of the plots should be adjacent.

(7). If the number of treatments is such that no practical plot arrangement can be devised to make up a sufficient number of pairs of adjacent plots for statistical study, it will be preferable to choose a layout that will allow for a determination of the soil variation which exists; i.e., Block or Latin Square.

(8). Intelligent placement of plots: (a) to take advantage of known soil fertility conditions, (b) to give all treatments equal exposure to possible soil differences, or (c) to make it possible to determine the effects of location variations. This should prove most effective in reducing the largest factor of error of our field experiments.

Practical Layouts: The different layouts as given below are arranged for tests which carry 9 or 10 replications of the number of treatments as indicated:

Irrigated Cane: (Basis: single watercourse plots)

(1). *For 2 Treatments:*

(A) *Checkerboard:* 20 plots: Ten in each of 2 levels, allowing 18 direct plot-to-plot comparisons, and giving 10 pairs of plots for statistical studies.

A X A X A X A X A X
X A X A X A X A X A

(B) *Series Arrangement:* 21 plots in one level, allowing 20 plot-to-plot comparisons, and 10 pairs for studies of significance.

X A X A X A X A X A X A X A X A X A X A X

(2). *For 3 Treatments:*

(A) *Checkerboard:* 36 plots: 12 plots in each of 3 levels, allowing

17 direct comparisons of A with X.
16 " " B with X.
no " " A with B.

and 9 pairs of both *A and X*, and *B and X* for statistical study.

A X B X A X B X A X B X
X A X B X A X B X A X B
B X A X B X A X B X A X

(B) *Series Arrangement:* (1) 30 plots: 10 plots in each of 3 levels, allowing

9 direct comparisons of A with X.
9 " " B with X.
9 " " A with B.

and 9 pairs of each for statistical study.

A B X A B X A B X A
B X A B X A B X A B
X A B X A B X A B X

(2) 32 plots: 16 plots in each of 2 levels, with

10 direct comparisons of A with X.
10 " " B with X.
10 " " A with B.

and 10 pairs of each for statistical study.

A B X A B X A B X A B X A B X A
B X A B X A B X A B X A B X A B

(C) *Latin Square:* 27 plots: 9 in each of 3 levels; 3 contiguous Latin Squares allowing for a determination of the effect of soil variation, and furnishing:

8 direct comparisons of A with X.
8 " " B with X.
8 " " A with B.

(Note: The 3 "Squares" may be separated if not convenient to run them together). In triplicate.

A X B   X B A   B A X
B A X   A X B   X B A
X B A   B A X   A X B

(3). *For 4 Treatments:*

(A) *Block:* 36 plots: 12 plots in each of 3 levels, allowing only a few plot-to-plot comparisons, but giving an arrangement by which the effects of location variation can be determined and its influence on the results allowed for:

A B C X   B A X C   X C A B
X C A B   A B C X   B A X C
B A X C   X C A B   A B C X

(B) *Series:* 39 plots: 13 in each of 3 levels, allowing 9 direct comparisons of A B, A X and C X—but no direct comparisons of A C and B X.

A B C X A B C X A B C X A
C X A B C X A B C X A B C
B C X A B C X A B C X A B

(C) *Latin Squares:* 32 plots: 8 plots in each of 4 levels. contiguous duplicated squares. Allowance is made for equalizing the effect of any soil variation and a few direct plot-to-plot comparisons are possible: 6 between A B, A X, B C and C X, and 2 between A C, and B X. Duplicated.

A B C X   B A X C
C X A B   X C B A
B C X A   C B A X
X A B C   A X C B

(4). *For 5 or more Treatments:*

(A) *Latin Square:* Single or duplicated; separated or contiguous, (Patterned after 3—C).

(B) *Block:* (Patterned after 3—A).

Non-Irrigated Cane: (Basis: the 1/10 acre, 8 line plot, except as noted).

(5). *For 2 Treatments:*

(A) Same as 1—B: 21 plots arranged down the slope.

(B) Same as 1—A: 2 plots wide, 10 plots long, down the slope.

(6). *For 3 Treatments:*

(A) *Checkerboard:* 36 plots: 2 plots wide and 18 plots down the slope, allowing 17 direct comparisons of A X and B X (none of A B) and 9 pairs of both A X and B X for statistical study.

X B X A X B X A X B X A X B X A X B
A X B X A X B X A X B X A X B X A X

(B) *Series:* 32 plots: 2 plots wide and 16 plots down the slope, allowing 10 direct comparisons and pairs of all varieties.

B X A B X A B X A B X A B X A B
A B X A B X A B X A B X A B X A

(C) *Latin Square:* (Basis: the 1/10 acre, 14 line plot).
(Same as 2—C)

(7). *For 4 Treatments:*

(A) *Block:* 36 plots arranged like 3—A, with 12 plots down the slope and 3 across.

(B) *Series:* 40 plots: 2 plots across and 20 down the slope, allowing 8 direct comparison and pairs of A C, 10 of A X, B X and B C, none of A B or C X.

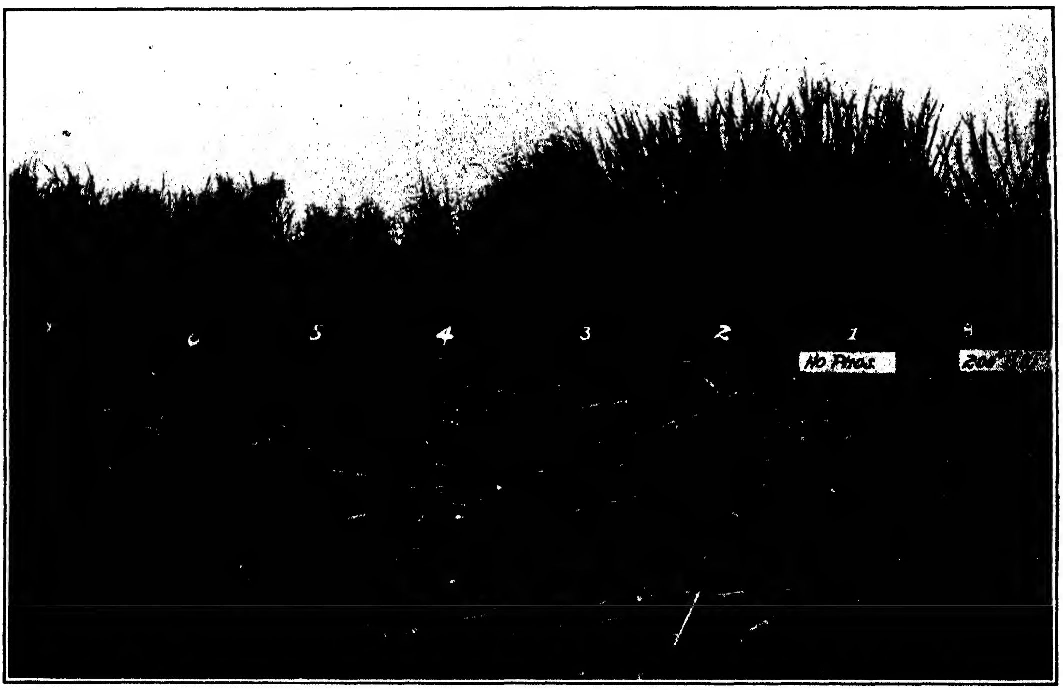
A X B C   A X B C   A X B C   A X B C   A X B C
C B X A   C B X A   C B X A   C B X A   C B X A

(C) *Latin Square:* Duplicated (Basis: 1/10 acre, 14 line plot). (Similar to 3—C)

(8). *For 5 or more Treatments:*

(Same as 4)

Border Effect: The 8-line plot which is preferred for non-irrigated cane tests, makes it practical to remove the 2 outer rows at each side of the plot and thus eliminate the possibility of error from border effect within the experimental area.



Even with a fertilizer as easily fixed in the soil as phosphoric acid, the border effect is noticeable. (Row 8 received 200 pounds P_2O_5 per acre; rows 1 to 7 received no phosphate.)

With a 6-line plot, only one row at each side can be cut out, for it is desirable that we have at least 4 cane rows (2 rows of bundles) from which to compute comparative acre yields. At least one guard line on each side of the plot must, however, be removed.

On irrigated cane, a practical method for eliminating border effect at the ends of the cane rows at the watercourse, has not yet been found. Hence, in variety testing, it is wise to plant varieties with similar growth habits in adjacent plots.

If the plots are so arranged that each treatment has a similar amount of plot exposure to roads, trails, track lines and ditches, it will not be necessary to pro-

vide guard rows or plots of crop cane to offset the effects of favored conditions. It is a good plan to equalize the amount of fertilizer as much as possible between the test area and at least two adjacent rows of crop cane.

Control Plots: Few of our present day field tests have plots which are untreated, and in place of this untreated check plot, we have included in our series of treatments, one group which receives the standard plantation practice. Hence, our modern check plot is the one which carries the proven variety or practice with which we are comparing some unknown. (In the designs submitted, the plots designated as X are intended to represent this control plot).

CONDUCTING THE EXPERIMENT (TO AVOID ERRORS)

In the preceding discussion of "The Plan" we have considered means of minimizing the effects of the unavoidable errors of location and of distributing the errors of preparation and planting, the errors which creep in during the progress of the experiment, and some of the harvesting errors. There is still much more that we can do to cut down that error which gives us an uneven stand, and to avoid errors at harvest. It is also essential that inaccuracies of measuring areas and of determining weights be avoided, since there is no way to eliminate such effects from our plot results.

Uniformity in all of the agricultural practices, except the one which is being tested, should be the keynote for conducting the field experiment.

Area Determinations:

On unirrigated areas where the plot boundaries are well defined, the determination of the plot areas should present but little difficulty. The desired shape and size having been chosen, the plot length is usually ascertained by dividing the area by the figure obtained from multiplying the average width of row by the number of rows to be included. It is well to check the area thus laid out, by taping the boundaries and a diagonal, since an error of .01 acre can give us a large per acre yield error on the commonly used one-tenth acre plot.

On irrigated fields where irregular shaped areas predominate, extreme care is needed to secure the correct plot acreage. Undoubtedly the most accurate determination is by the use of the traverse method of surveying, yet this method may not always be the most practical in our cane field work. Some plantations have used a modification of this method: they make a traverse of the outer boundaries of the experimental area and tape the individual plots therein. The measurements are then plotted to scale and a planimeter used thereon to find the individual areas. The sum total of these individual areas should then check with the total area.

When necessary to economize time, the stadia method has generally been in use. Its accuracy, although not quite comparable with direct tape measurements on level land or when measuring the individual plot boundaries, is sufficiently great when areas are to be expressed to only two decimal places. In the hands of careful operators and with stadia rods that can be read to hundredths of a foot, it is a quick and economical method of survey and may be useful in rough, hilly lands where accurate taping is difficult.

A combined stadia—cane row measurement, offers a practical and accurate method of securing comparable plot averages. The acreage of the entire test area is determined by stadia, and row measurements of all cane therein is made. From these figures, the total linear feet of cane row per acre is obtained and from this factor and the total cane row per plot, an accurate fraction of an acre to three decimal places is calculated.

If the plots have straight sides, their area can be quite easily and accurately determined without a transit. by taping the four sides and a diagonal, thus dividing the plot into triangles and measuring all sides. Errors in this form of survey are not apt to occur providing stakes are placed at the corners to avoid using different points for measuring the sides and the diagonal. A curved boundary line can be described by means of perpendicular distances measured from its chord, and areas therein computed quite accurately. This method deserves somewhat greater consideration than it has had.

Another method of determining areas is based on the lineal feet of row in the plot. This depends for its accuracy upon the figure which is used as the average width of row, which may be difficult to obtain if hapa lines are present and unless the land is quite level and uniformly furrowed out. Areas secured by this method are perhaps accurate to within .01 acre.

On unirrigated lands the plot areas should be measured to include the area which extends half-way to the outside row of the adjacent plot and one foot beyond the end stools of the row. On the irrigated lands, measurements should be made to the center of the watercourses, and to points 2½ feet outside of the end rows at the level ditches.

Staking and Mapping:

Experimental areas should be definitely and permanently marked for the life of the experiment. Natural boundaries as base points should be accurately located. Watercourses and level ditches make excellent plot boundaries in irrigated fields. Small trails, 2 to 3 feet wide, will suffice in young cane or unirrigated fields, but will have to be supplemented with a wire fence or a good big stake in each row before the cane covers in. Plot signs or stakes are important and help to stimulate interest and secure the cooperation of the field men. Every effort must be made to set off the experimental area from the surrounding crop cane, in such a way that laborers cannot unintentionally ruin the test.

Detailed maps showing the layout, plot treatments, and location of the test area should be made as early as possible, and field overseers should have copies of these maps in order to personally interest them in the welfare of the experiment.

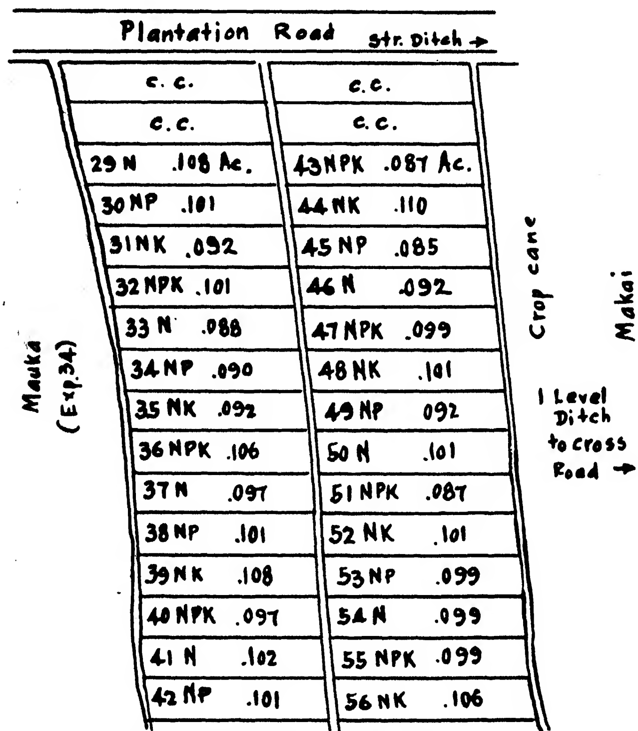
Uniformity in Operations (Except Those Under Test)

Preparation:

Plowing, subsoiling, harrowing and furrowing out must be done in such a way that all plots in the experiment will have similar conditions as regards depth and condition of seed bed, and width of rows. If the same implement and operator can do all of the machine work on the test area, and a whole gang rather than a

Pioneer Mill Co. Exp. 35, 1930 Crop

Field 30 - Honokawai. Elev. 350 ft.
Object - To determine the value of Phosphoric acid and Potash, alone and in combination.
Crop - H109, Second ratoon, previous crop harvested July 19, 1928.
Layout - 28 Irregular sized plots, each plot one watercourse.
Area: 2.742 Ac. net.



Fertilization lbs. per acre.

Plots	No. of Plots	Appl. #1 1st Season Am. Sul. 300# N	Ad. Phos. 300# P_2O_5	Pot. Sul. 250# K_2O	Appl. #2 2nd Sea. Ext. Amm. 50# N	Appl. #3 3rd Sea. N.S. 120# N	Totals N	P_2O_5	K_2O
N	7	450	—	—	250	774	260	—	—
NP	7	450	1429	—	250	774	260	300	—
NK	7	450	—	500	250	774	260	—	250
NPK	7	450	1429	500	250	774	260	300	250

O.H.L.
Aug. 1928

Am. Sul = 20% N Ad. Phos = 21% P_2O_5
N. S. = 15.5% N Pot. Sul. = 50% K_2O

The map of an experiment should show a sufficient amount of detail so as to serve as a guide for field operations, and as an aid in reestablishing the plot boundaries in case the stakes are accidentally removed.

few individuals can do all of the hand work, there will be less chance for non-uniformity in the plot operations that precede planting.

Planting:

A uniform stand of cane must be obtained before crop growth has proceeded to any great extent. Probably the factor which has the greatest effect upon the

stand is one that is closely connected with planting the seed. Good viable seed, of the same size, age. vigor, type and quality, that has been cut and handled in the same way, should be used throughout the entire area. Cuttings should be so planted that the rows receive approximately the same number of eyes per foot. Every effort must be made to avoid the necessity of replanting, but this must be resorted to until a uniform stand is secured.

Provision for replants may be a valuable practice, especially in semi-final variety tests. Single-eye seed pieces, planted in pots or in the field adjacent to the test area at the same time that the field test is planted, will provide the necessary replants to keep the plot stands comparable.

Cultivation:

In the cultural operations, where machines are used, let one operator handle all work on the test area, so that there will be little chance for the plots to receive varying treatments. If the area is under a cultivation contract, handwork throughout the plots should in general be quite uniform. When weeding is being done, care must be taken to avoid discrepancies of weed disposal, since considerable fertility is taken up by the weeds. Either they should be cut and left in the row, or they should be uniformly removed from the test plots. The same is true in regard to the removal of opala.

Fertilization:

An accurate and a uniform application of fertilizer is best obtained by carefully weighing it out for each plot, and having it applied line by line, by an experienced fertilizer gang. Skilled supervision of this work is absolutely essential to avoid errors of application and to constantly check the uniformity of application in the rows of cane.

Second season fertilization in big cane has offered a real problem. Putting it on by hand is difficult; cane is broken down and much of the fertilizer may remain on top of the trash and hence be not uniformly available to the plants. As it is usually put on in the irrigation water, the uniformity of its application is open to question because of the widely varying amounts of water that adjacent plots are apt to receive.

If a small barrel, graduated for the number of lines per plot, is used at the head of the watercourse, the application of second season nitrogen in water can be quite accurately made to the separate plots. This procedure is recommended for more general adoption if we are to have the same degree of control over second season fertilization that we give to first season applications.

Irrigation:

Recent data from Waipio indicate that there is considerable variation in the amount of water that may go on to adjacent plots during an irrigation round. This greatly complicates our attempt to give uniform treatment to our plots on irrigated lands. A check in cane growth, on a plot which may have received insufficient water to keep the moisture content of the soil above the wilting coefficient until the next irrigation, may never be noted, and yet its effect is certainly there

and in the final analysis will be checked up against the intentionally imposed treatment that the plot received. A sufficiency of irrigation water, so that the soil moisture content on all experimental plots will never reach that point at which cane growth ceases, is essential if we are to keep this complicating factor out of our results.

OBSERVATIONS (TO ASSIST IN INTERPRETING YIELD FIGURES)

Periodic observations during the growth of the crop, of the many factors which may influence it, will be exceedingly useful in interpreting the final yield figures. Statistical studies can only tell us whether or not the differences in yields are significant; the observational data if aptly recorded, will help us to understand the more probable reasons for the results obtained.

A convenient notebook form may be desirable for recording the factors which may affect the progress of an experiment. The more important factors which should be noted, at stated as well as at random intervals, are here enumerated.

(A). Comments on Weather: (Rainfall; periods of drought; abnormal temperatures; excessive winds, etc.).
 1. During the first 3 months of growth.
 2. During the "Boom stage".
 3. During the ripening period.

(B). Damage by Repressive Agencies: (Dates of; extent of; location by plots).
 1. Disease.
 2. Insect pests.
 3. Winds.

(C). Stand of Cane: (Specific, by plots).
 1. At 30 days.
 2. At 90 days.
 3. Replant. (Amount, date and location).

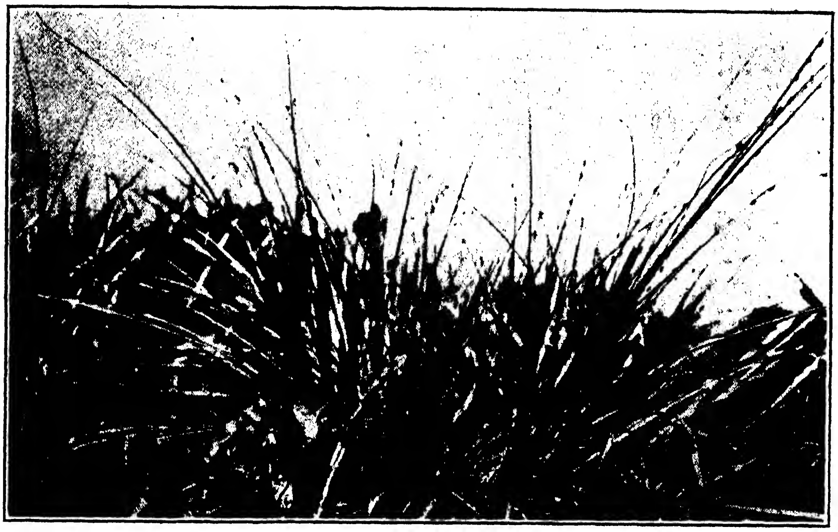
(D). Response to Treatments:
 1. General appearance and growth: At 90 days; at "closing in".
 2. Following application of fertilizers.

(E). Comments on Local Conditions:
 1. First rainfall after application of fertilizer.
 2. Soil moisture at times of important cultural operations. Locations of poor drainage; thin soil areas.
 3. Weed growth: amount, location, how long uncontrolled.
 4. Tasseling: amount, location.

(F). Growth Measurements.

(G). Preharvest Juice Sampling.

Short, concise statements, made only when there is something of value to record, may be preferred to a set form for recording observations. In either case, notes concerning factors which are liable to affect a fair comparison of plot yields, should be specific and definitely identify the area to which they apply.



Regular visits of inspection to observe accidental happenings that may affect plot yields are essential in order to catch such armyworm damage as is pictured here.

HARVESTING (TO GET ACCURATE YIELD DATA)

The carelessness or the negligence of some individual, or a lack of cooperation somewhere along the line from manager to field worker during the harvesting period, is undoubtedly responsible for many of the non-understandable results of our field experiments. It is at this period that a lack of understanding or an unsympathetic attitude will nullify all of the care and attention that has gone into the test during its progress. After carefully selecting, planning and conducting the test, its value is still unknown until accurate weights or samples of all cane produced are credited to the plots which grew it.

The harvesting of an experiment will without doubt add a little extra work to someone's regular duties during a very busy season. It will probably interfere somewhat with the regular plantation routine. It may even cost the plantation somewhat more to harvest than the ordinary crop cane. But if it was worth installing, it should now be worth careful harvesting, and any sacrifice in accuracy at this time will probably mean a loss of everything that has gone into the test. Cheap experiments will seldom be worth much; accurate results cost money.

Preparations for Taking Off the Crop:

Careful plans for harvesting the experiment should be made with the harvesting luna. Details agreed to when locating the test should be adhered to. Vigilant supervision of any preliminary cuttings for fire breaks, tracks, flumes, and for plot boundary lines, will be needed to see that this cut cane is left on its original plot.

A small gang of experienced cutters, to cut out the plot boundary lines ahead of the regular cutting gangs, will prove the value of this procedure and make it next to impossible for the regular gang to mix up the cane on adjacent plots when they come along.

Cane that has been "pushed back" at the watercourses offers a means of minimizing errors at harvest.

As an aid to the harvesting of test plots, the practice of pushing back cane on level ditches and watercourse boundaries may be valuable.

CUTTING:

Cooperation with the lunas of the cutting gangs is of primary importance and will do much to assure a uniform job of cutting and topping. Placing the most intelligent cutters on the boundary lines, will be most effective in keeping the cane from each plot segregated. The use of flags at the corners of the plots helps to mark them and reduces the chance of mixing up the cane.

On unirrigated areas, the practice of cutting and bundling two rows into one, will call for special attention in making sure that the two rows belong to the same plot. With 6-line plots, and with 8-line plots when the 6 center lines are to be weighed, the cutting of the last line of one plot with the first line of the next, allows a good method of discarding one guard row on each side. If the 4 center rows only of the 8-line plot are to be weighed, then the cutter is started on the stake line and discards the 2 outer rows he cuts.

While the cane is still on the ground, an inspection to locate such factors as rat damage, dead cane, excessive sucker growth, etc., is desirable in order to provide possible explanation of wide differences in juice characteristics which may appear on sampling.

LOADING AND TRANSPORTATION:

The loaders who handle the cane on test fields must have a definite knowledge of the plot boundaries. Constant supervision of loading should be maintained.

When portable track is used, insist that the cars are not filled so full that the cane is liable to fall off before it is weighed. A little extra attention in loading and in "pinning" the cane will not be amiss. Make sure that plots are "broomed up" on to their respective cars. Credit any later "pick-up" to the individual plots where it belongs. Make it a practice to follow the loaded cars out of the field, at least as far as the main track, to note losses from cars which are most likely to occur at this time. Wagon loading demands these same precautions.

When fluming to cars, flume one plot at a time, cleaning up all the cane on it before the next one is started. Send a "marker" down the flume after the last plot bundle is dropped in, so that the cars may be changed at the chute before the cane from the next plot arrives. Watch the loaded cars as they leave the flume station to note any loss therefrom.

Careful and distinctive marking of cars and of car tickets with their respective plot numbers will greatly facilitate accurate work and lessen chances for error after the cane has left the test field. Proper precautions and cooperation with the locomotive engineer and with the mill yard boss will prevent the "breaking-up" of your string of cars at such places as will cause confusion at the mill.

WEIGHING:

The best field technique will avail us little, unless an accurate weight of all cane grown on each plot is secured.

Keep scales adjusted and checked for accuracy.

Gross Weights:

If the cane is weighed in the field, not less than every third bundle should be carefully weighed on an accurate scale. (Our studies of bundle weights show that by weighing every third bundle, we can get an accuracy of within two pounds per bundle).

If the cane is weighed on the cars, sufficient time must be allowed on the scale platform for the scale indicator to be accurately read. Precaution must be taken to see that the cane in the car on the scale is not held up by stalks which project from the ends of adjacent cars.

Net Weights:

In figuring yields per acre on cane which is weighed in the field, it is customary to weigh a very few (perhaps only one or two) bundles per plot, then to clean these of trash and non-millable canes, and reweigh. The difference or tare is then multiplied by the number of bundles in the plot, and this product when subtracted from the gross weight, gives the net cane weight upon which our comparative plot yields are to be based.

Recent studies of tare figures, indicate the probability of introducing an error of considerable size through the inadequacy of this method of determining the plot tares. Twenty bundles (one from each of 20 adjacent rows of bundles) from two "Uniformity" tests harvested during wet weather, show the following averages:

(1). No of bundles harvested from 40 cane rows, 109′ long=416.
Range of individual bundle weights: 30 to 115 lbs.
Average bundle weight: 76 lbs.
Number of bundles tared: 20.
Range of tares: 10 to 40 lbs.
Average tare per bundle: 19.7 ± 6.63 lbs.

(2). No of bundles harvested from 40 rows: 543.
Range of individual bundle weights: 55 to 110 lbs.
Average bundle weight: 84.0 lbs.
Number of bundles tared: 20.
Range of tares: 10 to 25 lbs.
Average tare per bundle: 16.5 ± 2.7 lbs.

It is quite conceivable that the nature of the cane being harvested, the experience of the cutters, the climatic conditions, and the uniformity of the burn will affect the tare. It is doubtful however whether the desired accuracy for getting an average tare can be obtained without cleaning up and reweighing a more adequate sample than a single bundle.

For cane weighed in the cars at the mill, it is necessary to get accurate weights of the "empties" in order to determine the net cane. This accuracy cannot be secured if the empty cars are hurried over the scales, or if they are occasionally ridden by laborers who are cleaning them up. The use of a standard weight for a numbered car may be subject to error, particularly when the car is wet, and is therefore not to be recommended.

SAMPLING:

A continuous running juice sample from all cane of each plot as it goes through the first mill, gives the most representative and accurate composite for analysis. The cars from each plot should be unloaded consecutively onto the carrier.

Stick and bundle samples, taken in the field, are an unsatisfactory, yet often the only practical, method of getting an indication of the quality of the cane juices. Juices from these "made-up" or "field" bundles are usually expressed by a small mill or in the last three rollers of the big mill. The greatest factor of error in this method of sampling lies in the selection of the sample in the field. Unless it is truly representative of what the plot has produced, it is quite apt to be most misleading.

Recent studies of the relative accuracies of various methods of taking samples in the field, indicate that one or two field bundles picked up at random from a tenth-acre plot, are not likely to represent the cane there. Not until we take that number of field bundles which represents 8 to 10 per cent of the total number of bundles in the plot, can we expect to have a reliable and representative sample.

When a sample is made up, by selecting 20 or 30 sticks at random throughout the plot (choosing stalks only for an equal number of top and bottom pieces), there is some indication that such a sample is more reliable than the field bundle picked at random. Sufficient data are not yet available to establish the extent of accuracy which can be secured by this method, and so it will need to be used cautiously and its results interpreted with reservations.

The recently constructed "nut cracker" sampler offers a promising means of securing a more representative juice sample from a greater number of sticks than the "made-up" bundle usually carries.

Double cane knife samples, saw cut samples, and the use of the refractometer are still questionable methods for obtaining a high degree of sampling accuracy, and cannot be recommended for general use in sampling cane stalks from field experiments. These methods were designed primarily to detect differences in seedlings.

Strictly reliable results can come only from a sample which consists of *all* the cane grown on the various plots.

RESULTS

The field experiment aims to establish representative and relative mean yields from various agricultural practices. If we apply a nitrogenous dressing to a field of cane and shortly afterwards note a distinctly greener leaf color thereon, or again at harvest note more cane on the ground, this does not constitute an experiment; it is simply an observation, and no conclusion regarding the actual value of the nitrogen dressing can be made from it. Similarly, if we divide an 80-acre field into 2 sections and plant a new variety on one-half and our standard cane on the other half, after harvesting and weighing the cane from each half, we may have a demonstration, but we certainly have not an experiment that can be relied upon to guide the plantation in its decision to adopt or reject the new cane. In the final analysis therefore, accurate and sufficient weights of cane from many

definite plots, in order to establish valid average yields, must be the end result of our field experiment.

PRESENTATION:

Figures and comments given for any experimental harvesting should be presented by the persons who have conducted the test and those originally responsible for its installation, in order that all salient points may be sufficiently stressed and valued.

Plan and History: In presenting the results of a field experiment, a careful outline of its plan and conduct is essential to an intelligent understanding of what is to follow. The time of year when the test was conducted and when fertilizer was applied are of vital importance for proper interpretation of results. Choice of data to suit the experimenter who has conducted the test should be avoided.

A brief history of the experimental area's former crops and treatment, and of similar experiments that have been conducted nearby may be useful. The salient points from soil analysis data from the experimental or closely adjacent area should be available.

Yields:

Individual plot yields must be recorded. Their conversion to plot yields per acre must be accurate, and with cane as well as with juice and sugar figures, at least two decimal points should be recorded.

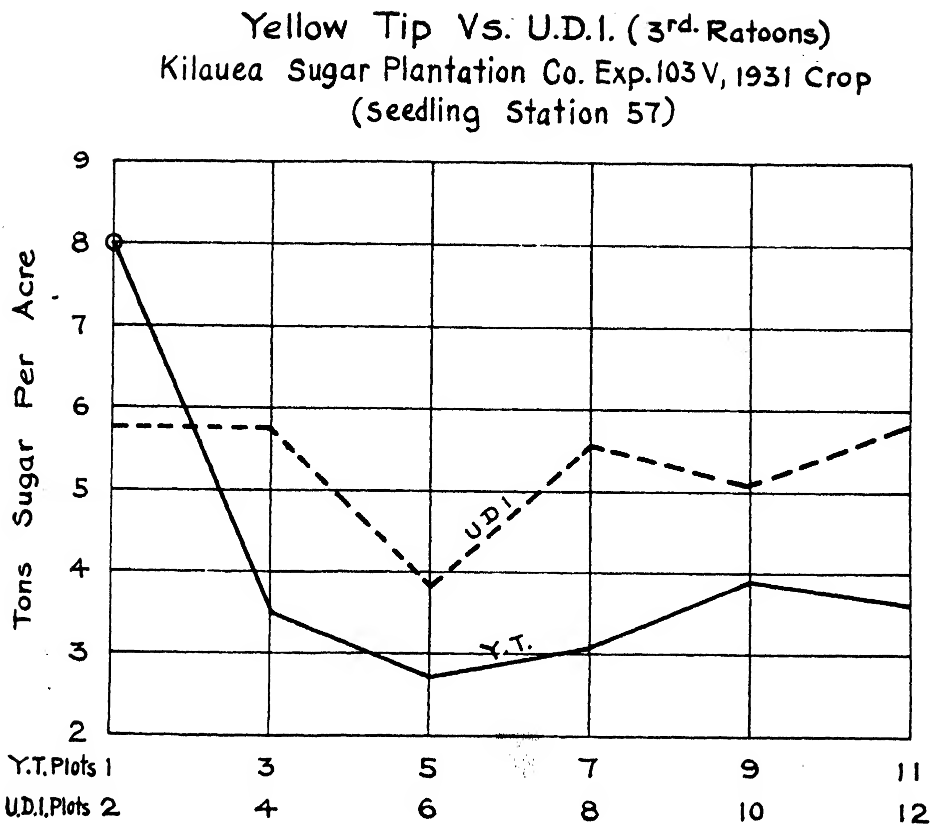
Since the modern experiment deals with treatments which are replicated a number of times, the various "Treatment" results will be further calculated and reported as averages of their individual plot yields, in tons of cane or sugar per acre.

Before summarizing the data which have been secured and are to be offered as the "Results" of our field test, careful editing of same is essential to note errors, omissions and inconsistencies. The editor who verifies the data is not justified in changing any of the originally submitted figures without distinctly marking his revisions.

After being verified, the data are generally arranged and summarized in the form of a "Table." This table should be as nearly self-explanatory as possible, and its data arranged in such a manner as to emphasize comparison and show relationships. Since long arrays of figures in tabular form often receive scant attention, a summary of the averages of varying treatments with their standard deviation should be prepared. If this summary forms the first page and is supported with the detailed results in the body of the report, the significant findings will be presented for immediate attention without loss of completeness.

For the presentation of individual plot results, the tabular form is perhaps the most difficult of comprehension. When distinctly marked on a map of the area. which shows the relative position of plots with respect to roads, ditches, gulches, trees, etc., individual plot yields (as T. C. A.) can be quite conveniently offered for detailed plot-to-plot studies, but there is a better way to present such data for general plantation use, i.e., by means of graphs which picture the facts presented.

A properly prepared graph enables one to observe variations and correlations within a series of data. Such things as the consistent superiority of one treatment



over another and the reliability or unreliability of individual plot results, are very nicely presented by use of line graphs, and make a more lasting and vivid impression than a column of figures.

Other types of graphs are also useful in portraying facts obtained from field tests.

Observations:

No set of experimental results should be considered as complete without vital observational data to accompany it. Suggestions for recording these data have already been made.

INTERPRETATIONS:

In analyzing results of our cane field experimental work, we are looking for reliable indications of trends that will be helpful in determining plantation policies. In past years, it has been quite simple to measure the large differences that were obtained from various treatments. With the heavier yields from improved cultural practices, our present day experiments must be so designed that smaller differences can be clearly measured. When similar treatments are repeated several times, the yields are almost sure to be different and hence quite apt to be misleading. Not always do we get differences in yields which are clearly apparent and distinct enough to show definite trends from treatments given. When we do, our interpretation is comparatively simple, e.g., a regular plantation practice in

Field 66 called for a total of 200 pounds of nitrogen. Four "Amounts of Nitrogen" treatments were replicated four times on a typical and representative area in order to determine whether it would be the part of good judgment to increase the amount of nitrogen on this field which was producing well over 70 tons of cane per acre. The test yields as secured were as follows (T. C. A.):

	First Series	Second Series	Third Series	Fourth Series	Average
From 150 lbs. N	80.6	73.3	80.6	82.6	79.3
From 200 lbs. N	84.2	79.2	83.7	86.6	83.4
From 250 lbs. N	89.4	93.5	89.1	94.8	91.7
From 300 lbs. N	95.8	94.0	90.3	99.5	94.9

The trend is there and it is quite definite. Providing that sugar increase has kept pace with cane increase, the management would not go astray in increasing their nitrogen application for this field up to at least 250 pounds per acre. In fact it would appear quite evident that they could not afford to do otherwise.

Definite and distinct correlations between treatment given and yields secured are not always apparent from an inspection of the average yields. Whenever an average value is recorded, some measure of accuracy is needed, if such a quantitative value is to have a definite meaning. When none is given, we unconsciously substitute our guess as to how accurate the given figure may be. For instance, if the average yield per acre from a series of seven plots is given to us as being 64.6 tons of cane, we are likely to assume that the yield is somewhere around 65 tons, perhaps not much less than 60 or more than 70 tons. If another seven plots in the test give us an average yield of 56.4 tons, other things being equal, we are apt to consider the average of the first set as about 8 tons better than the average of the second. Without a measure of the reliability of these averages however, we are not justified in accepting them as they stand and recommending plantation practices on the basis thereof.

Fortunately, we have at our disposal a statistical method of measuring the degree of reliability that can be placed on our experimental results. This is proving exceedingly helpful in measuring the dependance that we can place upon average yield figures, and if intelligently used by an agriculturist who has an appreciation of its limitations, it can furnish a safe guide and is a useful tool.

Significance of Yield Differences:

Reliability of Average Yields: No one treatment applied to a series of plots in a field test can be expected to give exactly the same yield on more than one plot. A series of plots on our test area is a sample. Our best judgment and experience have been called upon to make sure that it is a representative sample. By itself, one single plot cannot be considered an adequate sample, nor would the average yield of 2 plots be considered a reliable measure of a yield which might be secured from the whole field. If 10 plots were used, their average would be considered more reliable than the average from 2 plots; if 20 plots were used, their average would give us still greater confidence. Hence, it becomes relatively clear that as we increase the number of units in our sample from which the most probable average yield for the field will be calculated, the reliability we can attach to

this figure will be considerably enhanced, providing of course that its representativeness is not thereby changed.

Any series of yields from a group of plots which have been similarly treated will be grouped above and below a mean or average yield. If the individual yields are scattered widely from their average, we have evidence that the sample from which the average was computed was not an adequate one, and we cannot place much confidence in such average. On the other hand, if the individual yields are grouped rather closely around their average, we have much greater assurance that such an average is a reliable one. For instance, assume yields from individual plots as follows:

Example I. 4 plots: 83, 84, 85 and 88 tons.—Average 85 tons.
Example II. 4 plots: 80, 82, 84 and 94 tons.—Average 85 tons.

In both cases the average yield is 85 tons. In the first example, however, none of the individual plot yields are scattered far from this average, and obviously we can expect that the average from another similar group of 4 plots would fluctuate fairly close to 85 tons. In the second example, the wider range of individual variation from the average yield would indicate less reliability, and greater uncertainty that 85 tons could again be secured from 4 plots of a similar group.

Statistical measurements for field experiments: It is not the purpose here to go very deeply into the subject of statistical measurements for field experiments. One cannot go very far in his interpretation of our yield data, however, without recognizing the value of such measurements and using them much as one uses a tape or a scale to check up on measures of length and weight. As measures of accuracy therefore, we should be familiar with a few of the terms and their meaning, and the general use of some of the more usable tools that statistical methods have furnished us.

Error: The word "error" as used in statistical studies does not mean a mistake such as might arise from carelessness or incompetence. Rather it is a deviation between an observed value (such as a plot yield) and the most probable value (average). Such a deviation may be caused by factors which can be controlled or it may be due to accidental or uncontrollable conditions. If it is a constant error which persists, such as might be the case if a certain plot were specially favored by the position in the field, it will affect the representative character of the series. If it is an accidental or compensating error, it will take a position in a well defined statistical distribution about its most probable value, from which we can measure its effect upon results.

Standard Deviation: This term may be used to describe with a single value, the extent by which yields of a series of individual plots deviate from their average. It may be expressed in the original unit of measurement (*tons* of cane, *degrees* Brix, etc.), or as per cent of the average. It stands as a measure of the variability within the series of plots and its magnitude indicates the degree of such variability. It offers a basis for judging the typical character of the average yield or an idea of the nature of the individual yields from which the average was computed. When we know that the standard deviation of a group of "X" plots is 9 per cent (meaning an amount equal to 9 per cent of the mean or average yield)

we can immediately form a picture in which one-third of the plot yields are within a point 9 per cent above the average, and another third are scattered to a point 9 per cent below the average. In other words, if with this 9 per cent standard deviation the average yield was 85 tons of cane, we would expect about two-thirds (68 per cent) of the individual plot yields to be between 92.7 (85 plus [9 per cent of 85]) and 77.3 (85 minus [9 per cent of 85]) tons. If on the other hand, the standard deviation was only 4 per cent, the plot yields would be closer to their average: in this case, the majority would be between 88.4 (85 plus [4 per cent of 85]) and 81.6 (85 minus [4 per cent of 85]) tons. The variation in the second case being considerably less than in the first, we have our first indication of the reliability we can place in the average yield of the series.

If we are comparing the average yields from a set of "A" plots with the average from a series of "B" plots, the standard deviation for each set will indicate whether conclusions from such a comparison can be reliable. If one average has a large standard deviation and the other a small one, the averages cannot be considered as comparable. If both of the averages are accompanied by a large standard deviation, they may be comparable but we have an indication that the comparison would be untrustworthy, if both have a relatively small standard deviation we can proceed quite confidently to use the average figures for comparison.

The standard deviation may also be used to measure the reliability of averages, in which case it would indicate that if we had a series of such averages they would be distributed about their mean with the stated standard deviation. For instance, in a recent bundle weight study, 10 samples (each sample consisting of 10 bundles of cane) have an average bundle weight of 78.8 pounds, and a standard deviation of 2.3 pounds. We would expect from this to find two-thirds of the average weights to be between 81.1 and 76.5 pounds. Actually we do find 7 of the 10 averages to be within these limits and 3 to be slightly outside of them.

Probable Error: The amount of uncertainty of any plot yield may also be expressed in terms of the probable error of a single plot (PEs). This is .6745 times the standard deviation, and represents the range of variation, both above and below the average yield, within which *one-half* of the plot yields can be expected to occur.

Attention has been called to the fact that average yields alone are inadequate and must be accompanied by some index of their reliability. The probable error finds its use at this index. It describes the distribution of errors which are due to chance, and indicates the fluctuations from the average yield, which can be expected if yields from another similar series of plots were used to calculate this average. A small probable error does not, however, prove that the statistical values are trustworthy, for the chance variation with which it is concerned is affected by the adequacy of the sampling rather than its representativeness. A constant error might be included which the probable error can tell us nothing about. It is essential to keep these things in mind if the probable error is to be intelligently used.

In reporting average yields with their probable error we indicate the amount of variation which may be expected as due to chance under the same conditions and with the same number of plots. Thus an average yield of 75.8 plus or minus

3.8 tons of cane coming from 10 plots would tell us that the chances are even (1 to 1) that the average yield of another series of 10 plots grown under the same conditions would be between 72.0 and 79.6 tons.

Odds or Chances of Occurrence: The probable error of an average yield indicates even chances (odds of 1 to 1). The standard deviation indicates that there are 2 chances, that another plot yield would fall within its plus and minus range, against one chance that it would fall outside of this range (odds of 2 to 1).

For agricultural investigations, even chances are not considered adequate. and the generally accepted practice is to ask for a greater surety than odds of 1 to 1 or 2 to 1 afford us. When we have a difference in average yields which amounts to twice the standard deviation, or one which is 3 times the probable error, we have odds of over 20 to 1 and thus a fairly high degree of probability that such an amount is not due to chance. An amount that is 3 times the standard deviation or 4 times the probable error indicates a practical certainty that it cannot be attributed to errors of sampling and hence it is presumably due to some imposed treatment.

Application of Statistical Methods to Field Experiment Results:

The following illustrations show how the more generally used statistical methods can be used with the results of field experiments.

(A). The standard deviation as a measure of the degree of accuracy of an average yield:

"A" Plots	T. C. P. A.	d	d^2	
1	62	+ 5	25	
4	51	— 6	36	
7	68	+11	121	
10	53	— 4	16	
13	54	— 3	9	Average:
16	54	— 3	9	342
——	——	——	——	—— = 57
6	342	—16	216	6
		+16		

The average yield of the 6 "A" plots is 57 tons. The departures of the individual yields from this average are indicated in column "d": (the positive [plus] departures are always equal to the negative [minus] departures). The squares of the individual departures, column d^2, when summed, give the total *variance*, which in this case is 216. The total variance divided by the number of plot yields it represents gives the mean variance: $\frac{216}{6}=36$. The standard deviation is the square root of this mean variance: $\sqrt{36}=6$.

Mathematically this is the correct standard deviation for the example as cited. Student and other authorities, however, have recommended an additional factor of safety for crop tests when there are less than 25 replications. This factor is

introduced by using as a divisor of the total variance, one less than the number of plots:

$\frac{216}{6-1}$ or $\frac{216}{5} = 43.2$. The standard deviation thereby becomes $\sqrt{43.2}$ or 6.5.

The application of this standard deviation of 6.5 tons to the average of 57 tons of the "A" plots, tells us that if another set of 6 plots were grown under identical conditions we might expect to find two-thirds (4 plots) of them with yields between 62.5 and 51.5 tons and the other third (2 plots) outside of this range. This indicates that a conception of 57 tons as the yield which might be secured from the field as a whole, is quite liable to be wide of the actual figure which would be obtained.

With twice the standard deviation, 13 tons, we would expect to find 95 per cent of the plot yields of a similar test to fall between 70 and 44 tons, and there is an almost certainty that a range of three times the standard deviation, 19.5 tons above and below the average, hence 76.5 to 37.5 tons, would include all (99 per cent plus) of the plot yields of a duplicated test.

(B). The standard deviation as a measure of the significance of the difference between two average yields:

Eight "A" plots averaged 89.8 tons of cane and had a S. D. of 4.7 tons.

Eight "B" plots averaged 84.5 tons of cane and has a S. D. of 7.5 tons.

Is the difference between 89.8 and 84.5, which is 5.3 tons, a significant one?

The probability that shall be taken as significant is a matter of individual preference but the standard deviation will tell us what the probability is, and then we must decide whether we are to accept the margin of safety it indicates.

The standard deviation of a difference between two treatments is equal to the square root of the sum of the squares of the two separate standard deviations.

The S.D. of this difference (5.3 tons) is $\sqrt{(4.7)^2 \text{ plus } (7.5)^2}$ or $\sqrt{22.09 \text{ plus } 56.25}$ which is equal to 8.8 tons, and it indicates that the difference of 5.3 tons might well have been due to chance alone and hence cannot be considered as having been caused by the difference in treatment of the plots.

If these same average yields had carried smaller standard deviations, i.e., 89.8 tons plus or minus 1.1, and 84.5 tons plus or minus 1.3, we would then have had the following standard deviation of their difference:

$$\sqrt{(1.1)^2 \text{ plus } (1.3)^2} = \sqrt{1.21 \text{ plus } 1.69} = \sqrt{2.90} = 1.7$$

In this case the actual difference of 5.3 tons would be practically three times its standard deviation and the chances would be 369 to 1 that such a difference was due to the treatment given the "A" plots. Hence, we have an almost certainty that it is not a chance difference and can feel quite confident that it has been secured from adequate data and is therefore reliable.

In case the actual difference had been only twice the size of the standard deviation, our odds would have been in the ratio of 21 to 1 that such a difference was not due to chance; thus a fairly high degree of probability that the difference in treatment was responsible for the average difference in yield.

In place of measures of standard deviation, the probable error measure is

frequently used. In most American publications, a plus or minus sign (±) placed before a value, indicates the probable error of the mean. For instance: 80.1 ± 2.4 tons of cane, indicates a probable error of 2.4 tons of cane attached to an average yield of 80.1 tons. In our interpretation of differences in yield we would need to remember that it will take three times the probable error to give us the same significance which is indicated by twice the standard deviation.

The following table (1) may be useful in summarizing the odds and the degrees of probability indicated by different amounts of the Standard Deviation and the Probable Error:

(1) From page 241 "Principles and Methods of Statistics" by Chaddock.

Amounts of the S. D.	Chances of Occurrence	Amounts of the P. E.	Chances of Occurrence	Degrees of Probability
±0.6745	1 to 1	± 1	1 to 1	Equal
±1.0	2 to 1	± 2	4½ to 1	Favorable
±2.0	21 to 1	± 3	22 to 1	High
±3.0	369 to 1	± 4	142 to 1	Practical certainty

(C). Student's Method to interpret the significance of the average yield difference between adjacent paired plots:

LAYOUT

Treatment	A	B	C	A	B	C	A	B
Plot No.	1	2	3	4	5	6	7	8
T. C. A.	77	82	80	81	75	71	70	68
Treatment	C	A	B	C	A	B	C	A
Plot No.	9	10	11	12	13	14	15	16
T. C. A.	86	90	77	74	86	82	78	81
Treatment	B	C	A	B	C	A	B	C
Plot No.	17	18	19	20	21	22	23	24
T. C. A.	80	71	68	78	69	94	73	80

Plot Nos.	"A" Plots	"B" Plots	Difference (A-B)	(d) Deviation from the Av. Difference	d^2
1 and 2	77	82	— 5	9.4	88.36
4 and 5	81	75	+ 6	1.6	2.56
7 and 8	70	68	+ 2	2.4	5.76
10 and 11	90	77	+13	8.6	73.96
13 and 14	86	82	+ 4	.4	.16
19 and 20	68	78	—10	14.4	207.36
22 and 23	94	73	+21	16.6	275.56
Total			+46		
Pairs=7			—15		653.73
			+31		

$$\text{Average Difference} = \frac{31}{7} = 4.4$$

The Standard Deviation of this Average Difference $= \frac{\sqrt{653.73}}{7-1} = \sqrt{108.95}$ $= 10.4$. $\frac{\text{Av. Diff.}}{\text{S. D.}}$ or $\frac{4.4}{10.4} = .42$ which is Student's Σ and from his "Table of Odds" gives chances of about 5 to 1 that the figure of 4.4 tons is not due to chance. This 5 to 1 odds although favorable, is not considered a sufficiently high degree of probability that the amount of the difference is reliable or could be secured again.

RECOMMENDATIONS AND USE:

After the results of a field experiment have been analyzed by a plot-to-plot comparison and by the application of some statistical measure to determine their reliability, the agriculturist who has conducted the test will be in the best position to recommend further procedure.

No radical changes in plantation field policy or practices will be made on the basis of the results from a single test. Several repetitions of the test on successive crop will, be necessary if the test was a localized one. If it was a test whose results were to be applicable to the plantation as a whole or in a large part, repetitions of the test on different areas as well as through successive seasons will be in order.

If the probable error of the experiment was high. it will be advisable to check up on the possible reasons for such wide variation in plot yields. If the chance variation is too great, it may be best to discontinue the test on its present site and find a better place, rather than to repeat and again secure unreliable results. At any rate, it will be well to increase the number of replications in order to secure a more adequate sample.

If the probable error is low and we are still confident that the test area is representative and that constant errors are not being included, a repetition of the same test under the same conditions is assuredly in order.

SUMMARY

Since it is becoming more and more necessary for us to be prepared to determine smaller, significant differences than we have formerly measured, we find it necessary to take stock of our experiences and the findings of other agricultural workers, in the hope of developing an improved technique of field experimentation that will be in keeping with the high calibre of work which is existent in other branches of the Hawaiian Sugar Industry.

(1). The type of problem suitable for a field experiment on a sugar plantation should first be determined from the standpoint of its possible economic value to the plantation. With this information at hand, the expenditure of a certain sum of money to enable the agriculturist to secure a reliable answer from his experiment is justified.

(2). Factors which influence the yield of cane are not easy to control and only by using the best experimental technique can we hope to secure results that are accurate and not misleading. Hence careful planning of the test in order to reduce its errors, is our first essential.

(3). Conducting the experiment so as to avoid mistakes, and to keep therein such uniformity as will make the results comparable, is of no less importance than the plan which was made to minimize the effects of the compensating errors.

(4). Unbiased and pertinent observation data, taken during the progress of the test, will be invaluable when the yield figures are being interpreted.

(5). Adequate and intelligent supervision, and the cooperation of the entire plantation organization will be required at harvest time in order to get accurate yield data.

(6). Results will be recorded in terms of yields and observations. Their interpretation can best be made by the common sense judgment and experience of the man who has conducted the test, who has secured reliable data at its source. He can find a reliable guide and check his judgment by the application of statistical measures to his final yield figures.

Notes on Interpreting Experimental Results

By Y. Kutsunai

Before the figures are subjected to statistical methods it appears to be a good precaution to examine carefully the accuracy of the data from field experiments. The areas of the plots, the cane weights per acre, and the Brix and polarization of the juices are the fundamentals which reduced and simplified through various means permit the interpretation of the results, and, obviously, the basic data must be as free as possible from disturbing elements, which are usually excessive deviations and large mistakes.

Tons cane per acre, quality ratio, and tons sugar per acre for each plot, written directly on the respective plots on the map often reveal the fertility gradient, and the effect of an extraneous factor such as a ditch or a road, and furnish a basis for qualifying some of the yields as greater or less than normal for the locality.

The plot areas, if doubtful, can be surveyed again after harvesting the experiment. Some phenomenal yields have been traced to the mistakes in the surveying of plot areas.

The cane weights, in tons per acre, should be studied carefully, and any one that shows a suspicious figure should be recalculated from the scaleman's report. Chauvenet's Criterion may be used as an aid in deciding its disposition. The best guide, however, is the experimenter's intimate knowledge of the behavior of the plot in question during the crop life.

An example of Chauvenet's Criterion applied to cane yields follows (this step is not necessary if Student's Method is applied to the differences of paired plots):

	Tons Cane per Acre	Deviation	Deviation ^{2}
	69.4	— 8.1	65.61
	69.0	— 8.5	72.25
	67.2	—10.3	106.09
	80.1	+ 2.6	6.76
	80.1	+ 2.6	6.76
	99.2	+21.7	470.89
Total	465.0	+26.9	728.36
		—26.9	
Mean	77.5		$SD = \sqrt{\frac{728.36}{6}} = \pm 11.02$

In the table of Chauvenet's Criterion, Table I, column 2, in the line of $n=6$ is 1.897, the allowable limit is $\pm 11.02 \times 1.897 = \pm 20.9$. The last cane weight, 99.2, shows a deviation of 21.7, which is greater than the limit $\pm$ 20.9. The figure 99.2 should not be used in striking the average, if the experimenter's intimate knowledge of the plot likewise indicates that the figure is doubtful. Should it so happen that the fluctuations of the plot yields appear excessive but Chauvenet's Criterion fails to single out any one plot yield to be discarded, then the natural inference is that the plots are fluctuating widely due to extreme soil variation and the arithmetic mean of such plots is likely to be inaccurate.

An example of adjacent plot comparison as in Student's Method, tested with Chauvenet's Criterion follows:

Plots C Tons Cane per Acre	Plots B Tons Cane per Acre	Gain of C over B	Deviation	Deviation 2
67.8	63.6	+ 4.2	+ 1.24	1.5376
72.5	67.1	+ 5.4	+ 2.44	5.9536
68.9	63.5	+ 5.4	+ 2.44	5.9536
72.0	65.3	+ 6.7	+ 3.74	13.9876
63.6	65.7	— 2.1	— 5.06	25.6036
74.0	66.6	+ 7.4	+ 4.44	19.7136
60.8	67.1	— 6.3	— 9.26	85.7476
Total		+20.7	+14.30 —14.32	158.4972
Mean		2.96		

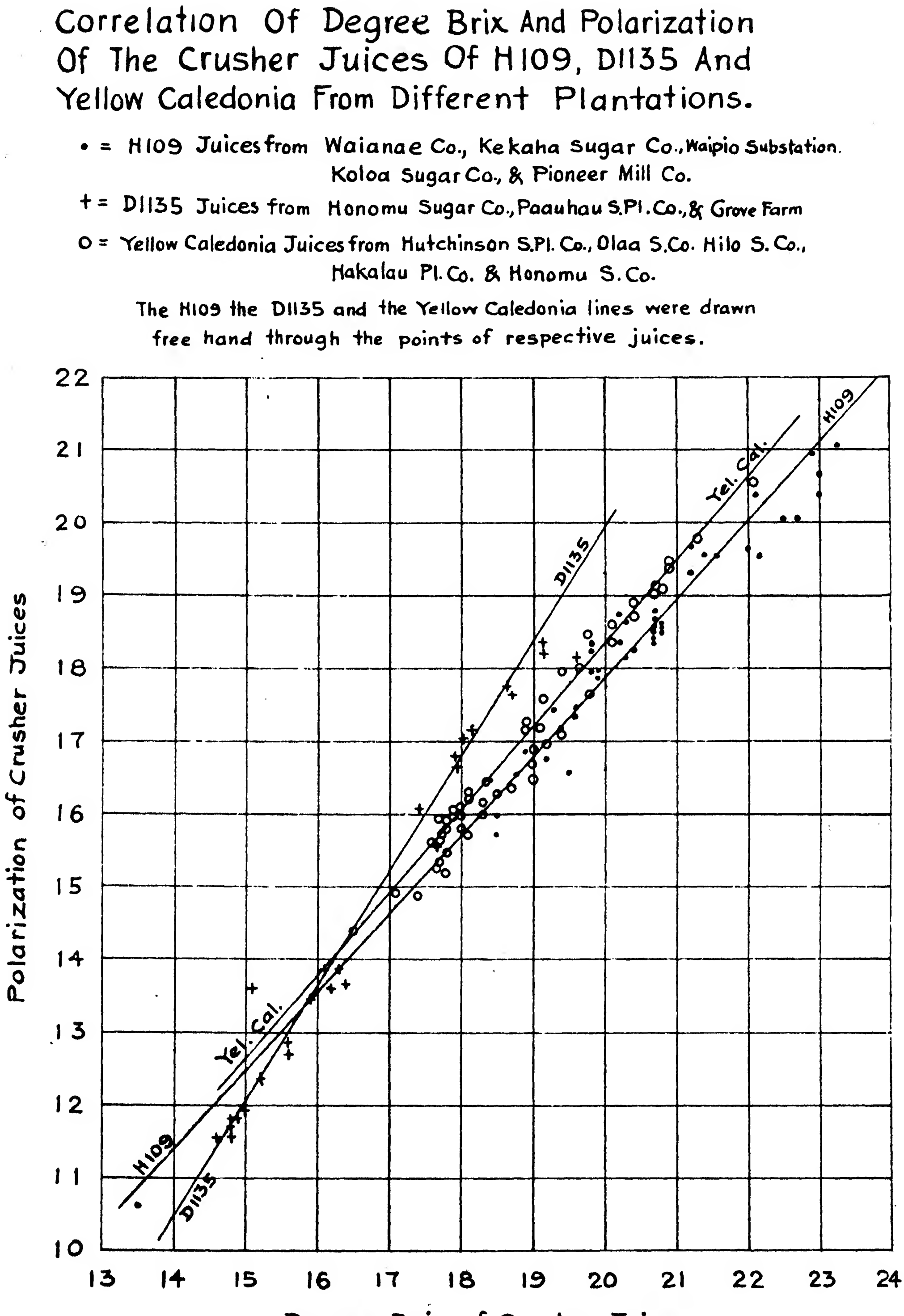
Standard Deviation $=\sqrt{\frac{158.4972^*}{7}} = \pm\ 4.76$. Chauvenet's Criterion from Column 2 and in the line of n=7 is 1.947. The allowable limit is $\pm 4.76 \times 1.947 = \pm\ 9.27$. The largest deviation is —9.26, which is very close to the limit 9.27. The experimenter's opinion based on the behavior of the plots can decide the disposition of —6.3 in the third column under the heading, gain of C over B.

The juices of a variety vary considerably from plot to plot. Usually this variation affects the sugar yields less than does the fluctuation in the cane weights, and in many cases the heavier cane yields are accompanied by the poorer juices so that the final results of the sugar yields are more or less compensated. In the extreme cases the poor juices and the heavy cane tonnage yield less sugar than the good juices and the light cane crop. The table below shows the compensating effect of the juices:

Plot No.	Tons Cane per Acre	Per Cent Recoverable Sugar	Deviation in Cane	Deviation in Per Cent Rec. Sugar
3	70.32	12.56	—15.62	+0.28
7	88.72	12.11	+ 2.78	—0.17
11	87.62	11.70	+ 1.68	—0.58
16	93.82	12.20	+ 7.88	—0.08
27	96.45	11.71	+10.51	—0.57
35	78.72	13.59	— 7.22	+1.11
Total	515.65	73.67	45.69	2.79
Average	85.94	12.28	7.62	.47
Per cent average deviation			8.86	3.79

The plots 3 and 35 show cane yields less than the average, but the juices are better than the average. The per cent average deviation in juice is less than that of cane weights.

* In an extremely accurate computation, the correction to be subtracted from the sum of the squared deviations is $(14.30—14.32)^2 \div 7 = +.00006$. The corrected sum of Deviation 2 is 158.4972—.00006=158.49714 and the S. D.$=\sqrt{\frac{158.49713}{7}}$


Correlation Of Degree Brix And Polarization Of The Crusher Juices Of H109, D1135 And Yellow Caledonia From Different Plantations.
• = H109 Juices from Waianae Co., Kekaha Sugar Co., Waipio Substation, Koloa Sugar Co., & Pioneer Mill Co.
+ = D1135 Juices from Honomu Sugar Co., Paauhau S.Pl.Co., & Grove Farm
o = Yellow Caledonia Juices from Hutchinson S.Pl. Co., Olaa S.Co. Hilo S. Co., Hakalau Pl. Co. & Honomu S. Co.
The H109 the D1135 and the Yellow Caledonia lines were drawn free hand through the points of respective juices.
Polarization of Crusher Juices
Degree Brix of Crusher Juices
H109
D1135
Yel. Cal.
10
11
12
13
14
15
16
17
18
19
20
21
22
13
14
15
16
17
18
19
20
21
22
23
24

Graph I.

The degree Brix and the polarization, on which the figure of per cent recoverable sugar largely depend, show a fortunate relation, i.e., when the degree Brix and the polarization of the juices of a variety are plotted on cross-section paper, the points fall into a line or a narrow belt which seems to be nearly straight. This characteristic of the sugar cane juices appears to be true for all varieties. With only a few exceptions the juices of a variety from many different localities when plotted together form a single line. Moreover the juices of the majority, if not all, of the varieties trace lines near to each other (see Graph I). However, when the juices in the stalks begin fermenting through deterioration prior to harvesting or delay in milling the harvested cane, the polarization goes down faster than the degree Brix, throwing the points out of alignment.

This correlation between the degree Brix and the polarization can be used in testing the correctness of the juice analyses. All the degrees Brix and the corresponding polarizations of the juices from one variety in a field test are plotted on a cross-section paper, the best fitting line is drawn free-hand among the points and the observations departing widely from the line may be discarded. In Graph II the points marked off are thought to result from erroneous observations. To save the labor of drawing an individual graph of juice characters for each variety in each test, a reference graph of juices of common varieties may be gotten up and the juices from the experiments on hand may be compared with this reference graph and the juice analyses which deviate much may be discarded.

Instead of the free-hand line, an arithmetic process may be used. The juice figures used are:

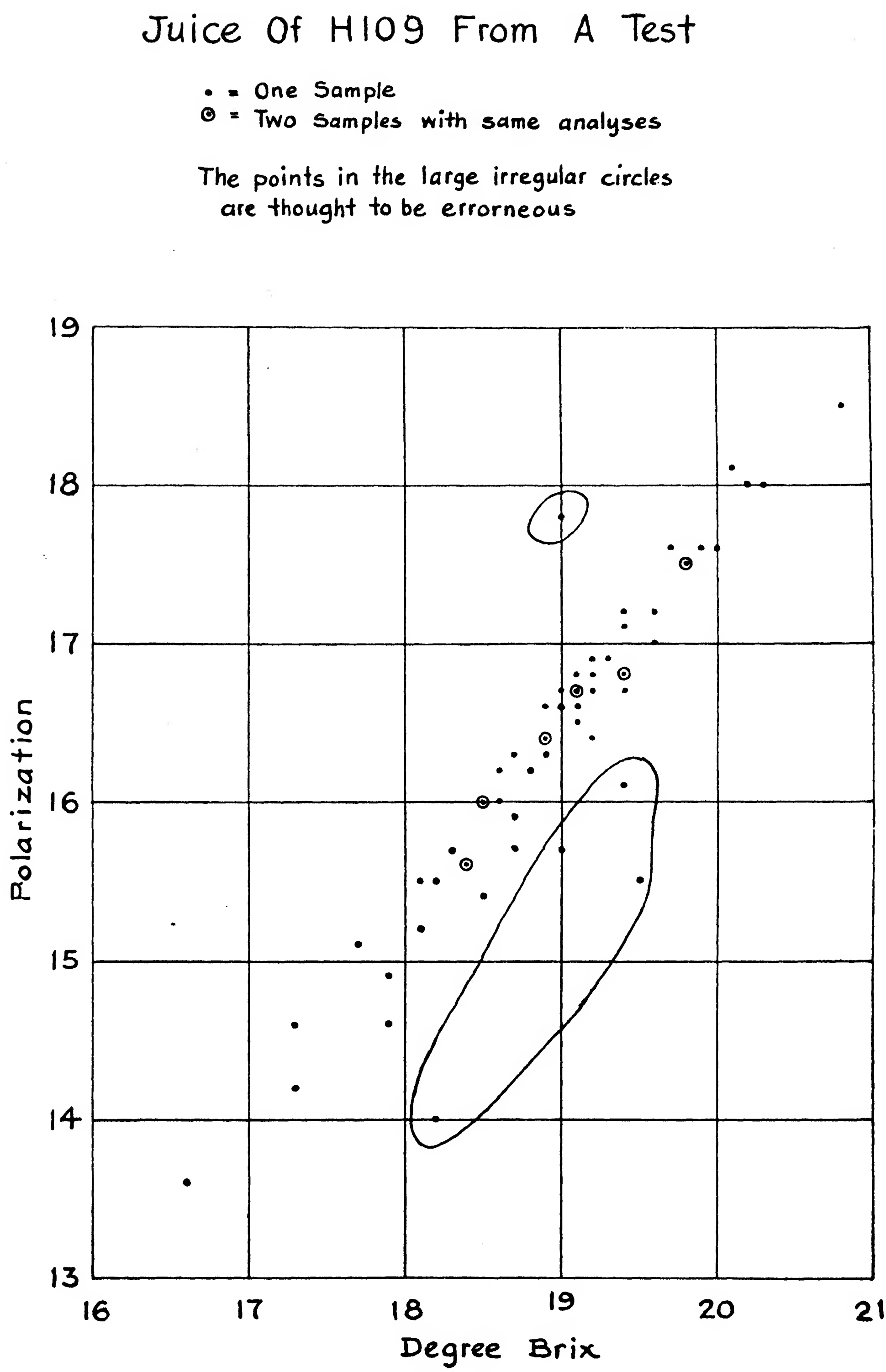
Sample No.	Degree Brix	Polarization
1	15.2	13.1
2	16.9	15.7
3	18.3	16.7
4	16.7	14.9
5	19.7	18.4

These values are formed into four totals, as in the following table for computing the values of two constants **m** and **a** in the straight line formula:

$$\text{Pol} = \text{m} \times \text{Brix} + \text{a}$$

Computation of **m** and **a**:

Brix	Pol	Pol x Brix	Brix 2
15.2	13.1	199.12	231.04
16.9	15.7	265.33	285.61
18.3	16.7	305.61	334.89
16.7	14.9	248.83	278.89
19.7	18.4	362.48	388.09
86.8	78.8	1381.37	1518.52
Σ(Brix)	Σ(Pol)	Σ(Pol x Brix)	$\Sigma(\text{Brix}^2)$


Juice Of H109 From A Test
• = One Sample
⊙ = Two Samples with same analyses
The points in the large irregular circles are thought to be errorneous
19
18
17
16
15
14
13
16
17
18
19
20
21
Polarization
Degree Brix

Graph II.

Symbolically,

$$m = \frac{\Sigma(\text{Pol} \times \text{Brix}) - \Sigma(\text{Brix}) \times \Sigma(\text{Pol}) \div n}{\Sigma(\text{Brix}^2) - \Sigma(\text{Brix}) \times \Sigma(\text{Brix}) \div n}$$

where n is the number of analyses (in this case 5),

$$a = \frac{\Sigma(\text{Pol}) - m \times \Sigma(\text{Brix})}{n}$$

Inserting the values in the place of symbols,

$$m = \frac{1381.37 - 86.8 \times 78.8 \div 5}{1518.52 - 86.8 \times 86.8 \div 5} = \frac{13.40}{11.67} = 1.148$$

$$a = \frac{78.8 - 1.148 \times 86.8}{5} = \frac{-20.85}{5} = -4.170$$

The formula of the straight line sought is:

Pol = 1.148 $\times$ Brix — 4.170

Graph III shows the five analyses and the straight line traced by the formula.

The analysis of Sample 2 may be discarded by inspection or Chauvenet's Criterion may be applied:

Sample	Brix	Actual Pol	Computed Pol	Deviation	Deviation^2
1	15.2	13.1	13.2	—0.1	0.01
2	16.9	15.7	15.2	+0.5	.25
3	18.3	16.7	16.8	—0.1	.01
4	16.7	14.9	15.0	—0.1	.01
5	19.7	18.4	18.4	0	0
					0.28

$$\text{S. D.} = \sqrt{\frac{0.28}{5}} = \pm 0.237$$

Chauvenet's Criterion for n = 5 in Column 2 is 1.839. The extreme allowable deviation is $\pm$ *0.237* $\times$ *1.839* = $\pm$ 0.44, hence analysis No. *2* which shows a deviation of + 0.5 can be discarded. In Graph III, this analysis is indicated by a circle.

Each item of the basic data successfully passing the above test is accepted for further study. The erratic ones that have been discarded are kept in the table of the original data and appropriately marked to show the decision reached.

The yield of each plot is transposed into tons sugar per acre and graphed on *cross section paper. Usually one plot from each of the two treatments, situated* in a comparable position are plotted on the same vertical line, another pair of plots on another vertical line, and so on until all the pairs are plotted. The yields of plots of one treatment are connected with one kind of a line, for example a solid line, and those of another with a different kind of a line, such as a broken line. The general sequence of the plots in the graph is the sequence of the plots in the field itself and the direction of the "march" is not changed unless for a good reason.

"Comparable position" means not only close proximity, but also uniformity of exposure to extraneous objects such as ditches, tracts of waste land, roads, or

Analyses of D1135 Juices Modified Slightly For the Example of Applying Chauvenet's Criterion

Juice Analyses

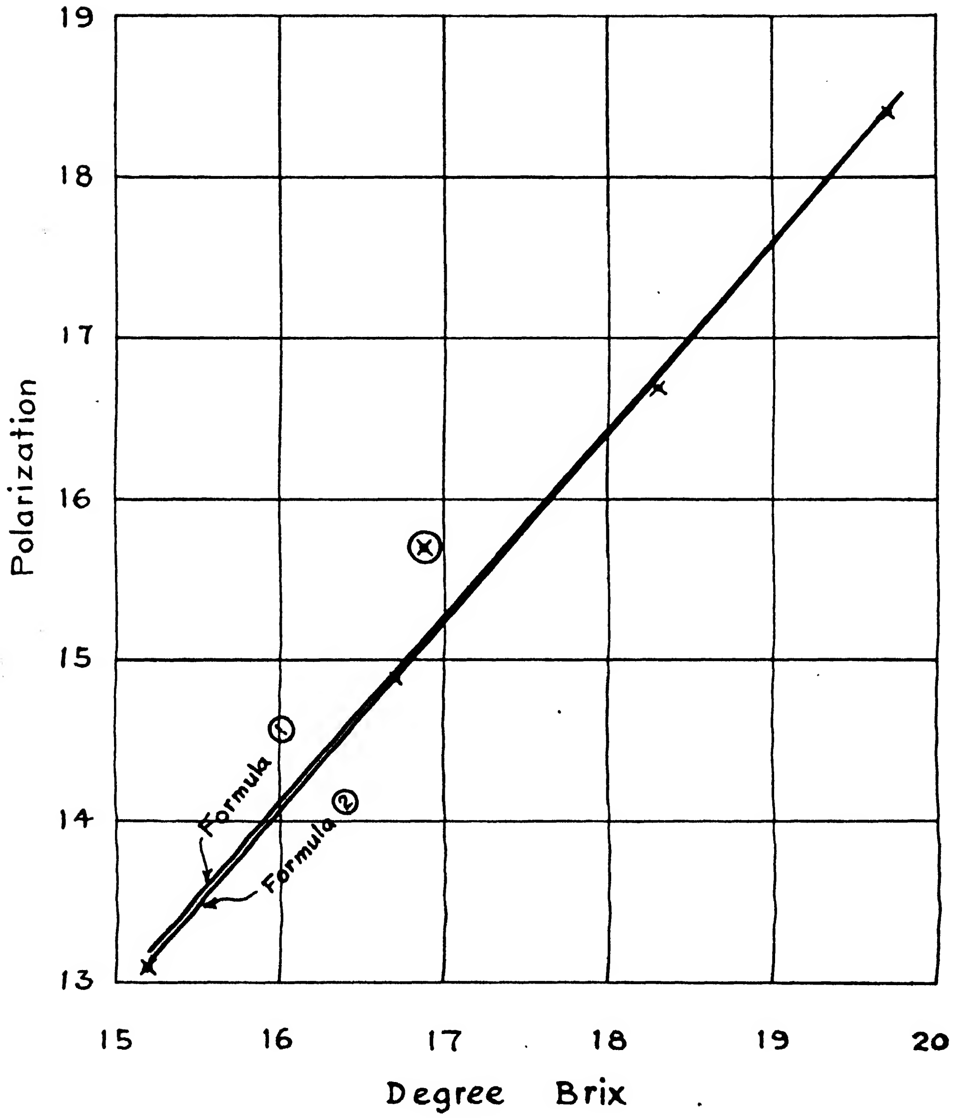
Sample	Brix	Pol.
1	15.2	13.1
2	16.9	15.7
3	18.3	16.7
4	16.7	14.9
5	19.7	18.4

The straight line is traced by

Pol. = 1.148 X Brix - 4.170 (1)

After eliminating sample 2 formula changes to

Pol. = 1.172 X Brix - 4.705 (2)



Graph III.

adjoining cane, and homogeneity in the soil fertility common to each of the paired plots, for instance knolls, depressions, or slopes.

If the treatment lines of the entire series of at least six pairs of plots do not cross, the experimental results can usually be accepted with confidence and the average yields of the two treatments are comparable, showing gain or loss in sugar.

If, on the other hand, the treatment lines crisscross each other often, the indication is that the treatments are without difference as far as the effect on the crop is concerned or else the plot-to-plot fluctuation is too large for the test. No further computation clarifies the situation.

Either the cane weight or the juice characteristics can be graphed if the experiment in question is thought to affect either one specifically but the most important of all is the graphing of the sugar yields in every case studied.

This method is well adapted for the study of two constants such as two varieties, off-barring against non-off-barring, chemical weed control vs. animal cultivation, etc. By applying the same process progressively, a variable involving three or more quantities say, 100, 200, 300, and 400 pounds per acre of fertilizer may be examined. First the plots of the two treatments 100 and 200 are graphed, then 200 and 300, and lastly 300 and 400. In order to obtain a large difference in the yields, 100 and 300 or 100 and 400 are often graphed whenever possible in addition to other usual combinations.

In case a decision can not be reached by the graphic method, statistical mathematics is tried. For a comparison of two treatments or two varieties in adjacent plots, Student's Method is an excellent one.

An example of two varieties in adjacent plots follows:

Tons Sugar per Acre U. D. 110	Tons Sugar per Acre Adj. Yel. Tip	Gain of U. D. 110 Over Yel. Tip	Deviation from Mean Gain	Deviation²
5.45	5.07	+0.38	+0.02	0.0004
5.73	4.62	+1.11	+0.75	0.5625
5.21	5.05	+0.16	—0.20	0.0400
5.37	4.56	+0.81	+0.45	0.2025
4.88	5.15	—0.27	—0.63	0.3969
5.38	5.42	—0.04	—0.40	0.1600
+ Total		+2.46	+1.22	1.3623*
— Total		—0.31	—1.23	
Net Total		+2.15	—0.01	
Arithmetic Mean		+0.36		

$$\text{S. D.} = \sqrt{\frac{1.3623}{6}} = 0.48 \quad z = \frac{0.36}{0.48} = 0.75.$$ Odds from Student's Table, Table II, corresponding to $z = 0.75$ and $n = 6$ are 11.8:1, much lower than the conventional limit of significance of 30:1 odds. Whether the gain of 0.36 ton

* For extremely accurate work the sum of the squares of the deviations is corrected by subtracting (the square of the net total in the deviation column) ÷ the number of items—for example: $1.3623 - (0.01^2 \div 6) = 1.36318$.

sugar per acre can be considered real or not depends on the past experience of the investigator.

When a plot of a new variety is in between two plots of a check variety, the yield of the new variety is compared with the average of the two check plots and the differences thus obtained are tested with Student's Method. The components of each triplet must be not only adjacent to each other but also free from inequalities in exposure or obvious fertility value.

All experiments involving two constants such as cultivation tests, some of the plant food tests, kinds-of-fertilizer tests, cut back vs. no cut back, and others, can be handled in the same way.

Experiments with one variable, such as tests with different amounts of a fertilizer, require the determination of the best amount to apply in addition to the statistical significance of the results.

The several amounts of the fertilizer may be considered as several constants and Student's Method may be applied to the difference in yields of adjacent plots receiving different amounts of the fertilizer.

Sometimes in an experiment for the amount of fertilizer to apply, the difference in each successive increase of the fertilizer causes so small a difference in the yield that no statistical significance can be obtained. This difficulty is occasionally overcome by comparing the plots receiving a small amount of the fertilizer with those obtaining rather a large quantity. For instance if 150 pounds of nitrogen per acre shows a small gain not statistically significant, over 100 pounds of nitrogen, then 200 or 250 pounds may be compared with 100 pounds; and, when the larger increment in the fertilizer gives a distinct increase in the crop, the small gain from 150 pounds of nitrogen over 100 pounds may be considered certain. Due consideration must be exercised however in choosing the heavy fertilizer plots for the comparative purposes on account of the tendency of an excessive amount of a fertilizer to impair the juices so much more than can be made up by the increase in the cane weight, that the final sugar production may be nearly equal to or even less than that from a much smaller amount of the same fertilizer.

The average sugar yields from each amount of fertilizer are graphed, a free hand curve is passed through the points of sugar yields, and from the curve the optimum amount of the fertilizer to use can be estimated.

It is a good precaution to graph the path of average cane weights and the quality ratios. From these two lines, the free hand line of sugar yields can be checked at intermediate points.

Experiments dealing with varying degrees of a single factor such as amount or time of application of irrigation water, a single plant food element and the like may be handled by this graphic method. (Graph IV.)

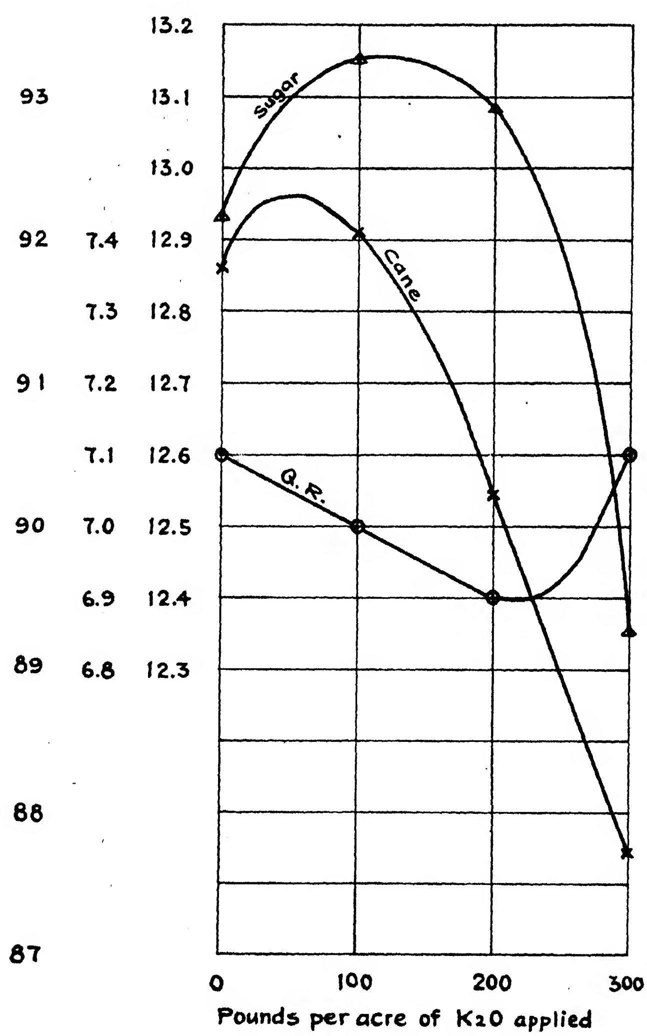
The yield curve computed by the method of Spillman is excellent for interpolating the sugar yields between any two quantities of a variable factor tested.

Experimental results from tests with two variables can be shown by a frequency surface similar to Graph V or more satisfactorily by a model similar to the one shown in photograph (A).

The Increasing Amounts Of K2O Affecting The Per Acre Yields Of Cane and Sugar

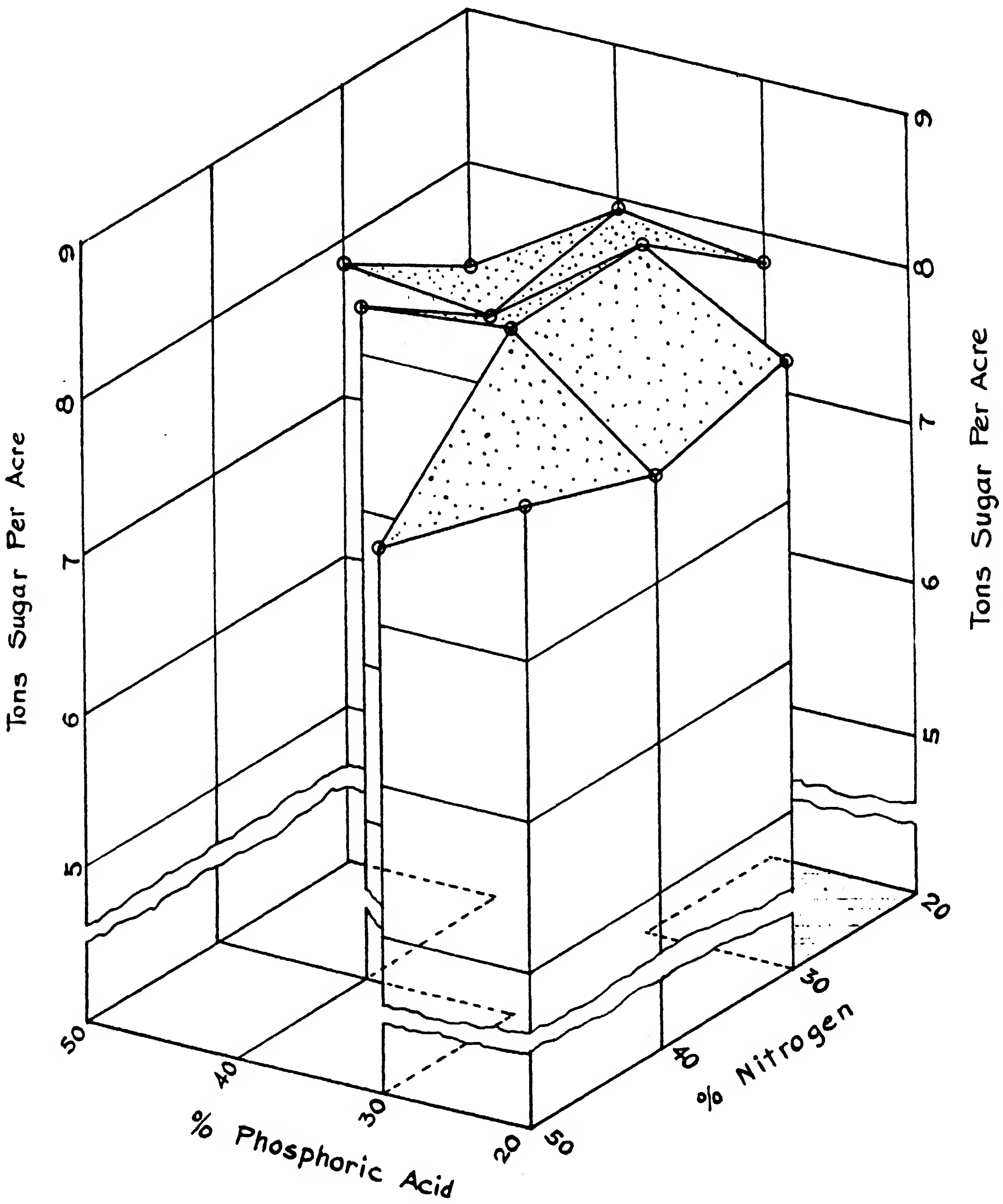
Harvesting Results Used

Plots	No. of Plots	Fertilizer Applied lbs. P.A. N.	P_2O_5	K_2O	Cane T.P.A.	Q.R.	Sugar T.P.A.
A	6	256	200	0	91.80	7.1	12.93
B	6	256	200	100	92.03	7.0	13.15
C	6	256	200	200	90.22	6.9	13.08
D	6	256	200	300	87.70	7.1	12.35



Graph IV.

Tons sugar per acre from combinations
of various percentages N, P_2O_5 and K_2O
The total of N, P_2O_5 and K_2O is 100%



Grah V.

The surface of the model represents 8 tons sugar per acre. Clearly the model shows that the heavier the fertilizer the earlier it must be applied.

Fertilizer tests laid out according to the triangular system in which the sum of the three factors equal 100 per cent may be classed under the two-variable experiments, and the rectangular model may be used if so desired, because the amounts of any two fertilizers can be taken as variable while studying the harvesting results and the third fertilizer can be left out of consideration until the decision is reached.

A model drilled to represent the layout of the triangular coordinates as shown in photograph (B) is just as simple to interpret as the rectangular model.

Graph V also represents the data of this triangular test in the form of a frequency surface.

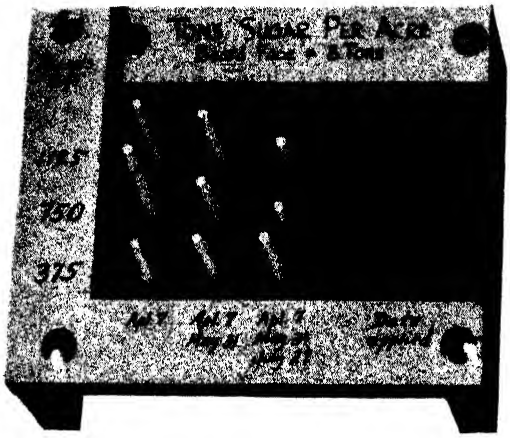
If three factors vary independent of each other, for example, nitrogen increasing 75, 150, 225 and 300 pounds per acre, phosphoric acid 100, 200, 300 and 400, and potash 0, 100, 200 and 300, the harvesting results may be gathered in a tabular form as shown below:

SUGAR YIELDS, TONS PER ACRE
(Reconstructed from the yield curves)

	0 Lbs. K_2O	100 Lbs. K_2O	200 Lbs. K_2O	300 Lbs. K_2O
	75 Lbs. N			
100 lbs. P_2O_5	7.6	7.4	7.2	
200 " "	7.5	7.3	7.1	
300 " "	7.3	7.2	7.0	
400 " "				
	150 Lbs. N			
100 " "	8.0	7.9	7.8	
200 " "	8.1	8.1	7.7	
300 " "	7.9	7.8	7.7	
400 " "	7.7	7.6	7.6	
	225 Lbs. N			
100 " "	8.1	8.3	8.2	8.0
200 " "	8.2	8.4	8.3	8.1
300 " "	8.1	8.4	8.2	8.0
400 " "	7.9	8.2	8.0	7.9
	300 Lbs. N			
100 " "		7.6	7.7	7.5
200 " "		7.8	7.9	7.7
300 " "		7.9	8.0	7.8
400 " "		7.9	8.0	7.7

An experiment as extensive as the above is more suitable for pot tests than for field tests *even after eliminating the obviously poor combinations.* The four sections of the table are made up into a model, and the center of high yields in each section is estimated as follows:

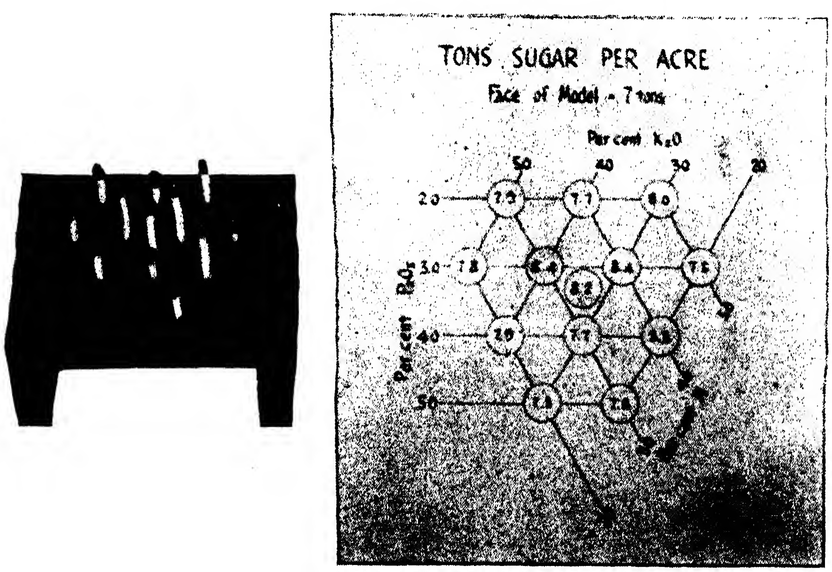
Pounds per Acre			Sugar Yield Tons per Acre
N	P_2O_5	K_2O	
75	100	0	7.6
150	200—	50—	8.1
225	200+	100+	8.4
300	300	200	8.0



(A) The model represents the sugar yields from a test for different amounts and time of applying a mixed fertilizer (M. F.) as a spring dressing.

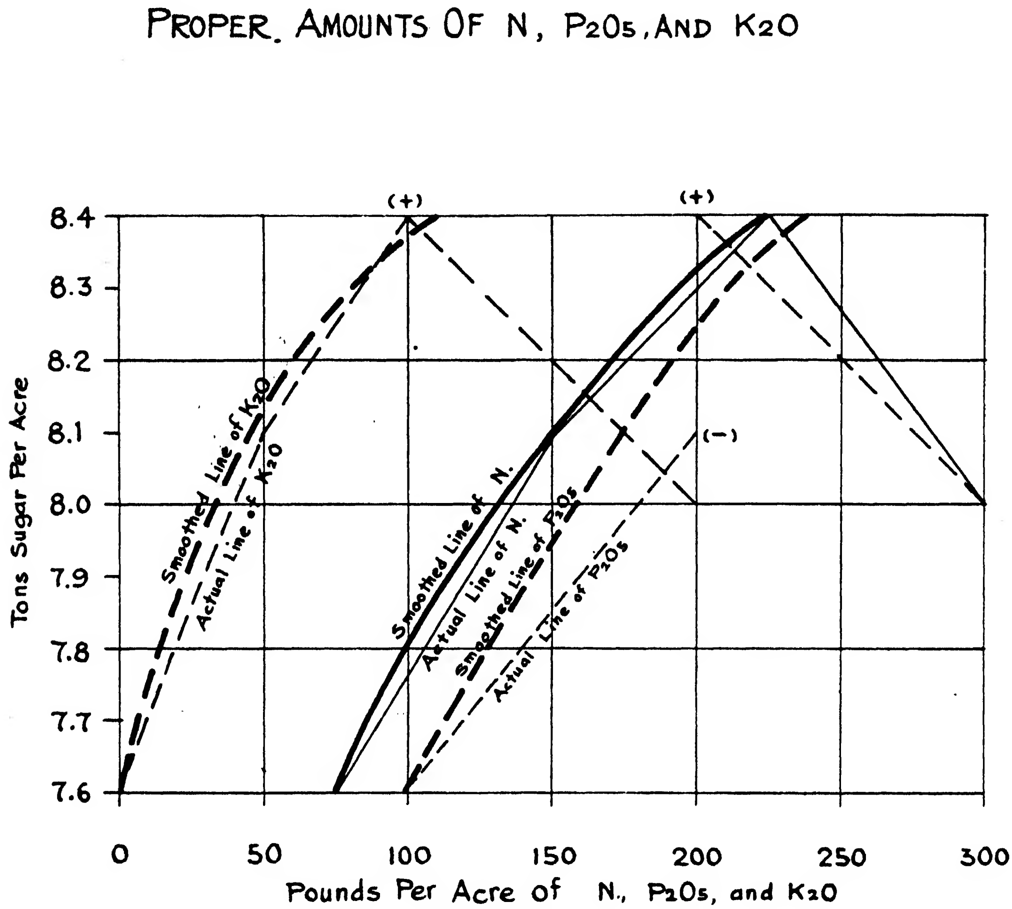
The harvesting results shown in the photograph are:

Plots	Pounds M. F.	Doses	Date Applied	Sugar Yield
A	375	1	April 7	9.07
B	"	2	April 7, May 31	9.21
C	"	3	April 7, May 31, July 27	9.11
D	750	1	April 7	9.76
E	"	2	April 7, May 31	8.99
F	"	3	April 7, May 31, July 27	8.33
G	1125	1	April 7	9.42
H	"	2	April 7, May 31	9.12
I	"	3	April 7, May 31, July 27	8.41



(B) In this photograph the composition of the best ratio appears to be 37 per cent nitrogen, 32 per cent phosphoric acid, and 31 per cent potash.

These figures when found reliable are plotted on cross section paper and free hand curves are drawn through the points of the ascending yields. The descending branches of the curves are of no interest in the practical work. From these free hand curves (Graph VI), the following table of best proportions is constructed:



Graph VI.

	Pounds per Acre		Sugar Yields Tons per Acre
N	P_2O_5	K_2O	
75	100	0	7.6
87	112	6	7.7
102	130	15	7.8
117	146	25	7.9
132	161	35	8.0
150	175	45	8.1
168	191	63	8.2
198	210	83	8.3
230	237	110	8.4

An easy but lengthy mathematical method suitable for studying many variable factors is described in chapter 14, "Method of Correlation Analysis," by Mordecai Ezekiel.

Plant food tests often do not contain sufficient replication of the plots for applying statistical analysis. The conclusions drawn are indicative, but not quantitative. However, the number of comparisons from various layouts is of interest.

P_2O_5 and K_2O only are tested when N is applied to all the plots. The treatments are N, P, K and PK and the possible comparisons are:

NPK vs. NP, NK and N
NP vs. NK and N
NK vs. N

When nitrogen also is tested, the treatments are NPK, NK, PK, N, P, K and O (no fertilizer) and the comparisons increase to 22 as follows:

NPK vs. NP, NK, PK, N, P, K and O
NP vs. NK, PK, N, P, K, and O
NK vs. PK, N, P, K, and O
PK vs. N, P, K and O

A small amount of a certain fertilizer, particularly P_2O_5 and K_2O, may become fixed near the surface of the ground and remain unavailable to the cane plant. No response of the cane crop to a fertilizer may mean sometimes non-availability due to faulty application rather than a sufficient supply in the soil.

In all cases the common sense and the general knowledge of the experimenter take precedence over the statistical methods.

TABLE I
CHAUVENET'S CRITERION

Compute standard deviation by the usual formula, $S.D. = \sqrt{\frac{\Sigma D^2}{n}}$

Enter Column 1 with the value of **n** used in computing the foregoing standard deviation. In the same line and in Column 2 the correct value of the limit of deviation is found. Multiply the standard deviation by the limit of deviation. The product is the limit of allowable fluctuation.

Column 1 n	Column 2 Limit of Dev.
3	1.694
4	1.771
5	1.839
6	1.897
7	1.947
8	1.991
9	2.031
10	2.066
11	2.098
12	2.127
13	2.154
14	2.181
15	2.203
16	2.225—
17	2.245—
18	2.264
19	2.282

Column 1	Column 2
n	Limit of Dev.
20	2.300
21	2.316
22	2.332
23	2.346
24	2.361
25	2.374
26	2.387
27	2.400
28	2.412
29	2.424
30	2.435—

Studies in Experimental Technique—Shape, Size and Replication

FROM THE 1931 HAKALAU BLANK TEST

By Ralph J. Borden

A typical area of unirrigated, first ratoon, Yellow Caledonia cane at Hakalau Plantation, which had been uniformly fertilized and handled, was harvested in one-twentieth acre, six-line plots, in order to sample the uncontrolled variation within the field, and to afford data for a statistical study to assist us in determining how such factors as plot size, shape, and replications might affect the reliability of average yields therefrom. This same area had been harvested in a similar manner, as plant cane some twenty-one months previously, and for those who are interested in noting the persistence of the natural fertility trends in our cane fields, we offer the line graphs of Fig. 1, wherein the 1931 plot yields show a distinct tendency to follow the yield curve of the 1929 plant crop.

The plan of the Hakalau Blank Test, together with information necessary to a complete comprehension of the data which follow, is shown in Fig. 2. A summary of the many individual studies that were made from the data is given in Table I. Grouping and comparisons of particular interest are discussed hereafter in some detail.

Evidence of Variation

Using the coefficient of variation (C. V.) as a measure of the amount of uncontrolled variation that exists within the members of a group of plots, we have an indication of the range of plot yields which have entered into the average yield. For instance: the twelve plots of Column I have the same average yield as the twelve plots of Column II, i.e., 71 tons. The Column I plots, however, have a coefficient of variation of 6.2, and we can therefrom conceive of two-thirds of this group of twelve plots as having yields of from 66.6 to 75.4 tons.* The twelve plots of Column II have a C. V. of 10.6; hence we picture two-thirds or nine of these plots with yields which are between 63.5 and 78.5 tons,† thus a wider range of variation than exists between the plots in Column 1. Hence the average yield of 71 tons for the twelve plots of Column I is a more reliable figure than the 71-ton average for the Column II plots, since the range of plot yields which enter into it is not so wide.

Examination of the data in Table I shows a considerable difference in the range of variation that exists in the area harvested. The two center Columns, II and III, show considerably more variation than Columns I or IV. In Section 1, which borders the government road, we find the least variation of any of the groups of twelve plots, while Section 4, which borders the railroad track, appears from its C. V. of 9.27 to be somewhat more spotty. The twenty-four plots in each of the horizontal divisions, 1 and 2, show less variability than those in the vertical divisions, 3 and 4.

* 71 tons ± 6.2% which is 71 tons ±4.4 tons or 66.6 to 75.4 tons.

† 71 tons ±10.6% which is 71 tons ±7.5 tons or 63.5 to 78.5 tons.

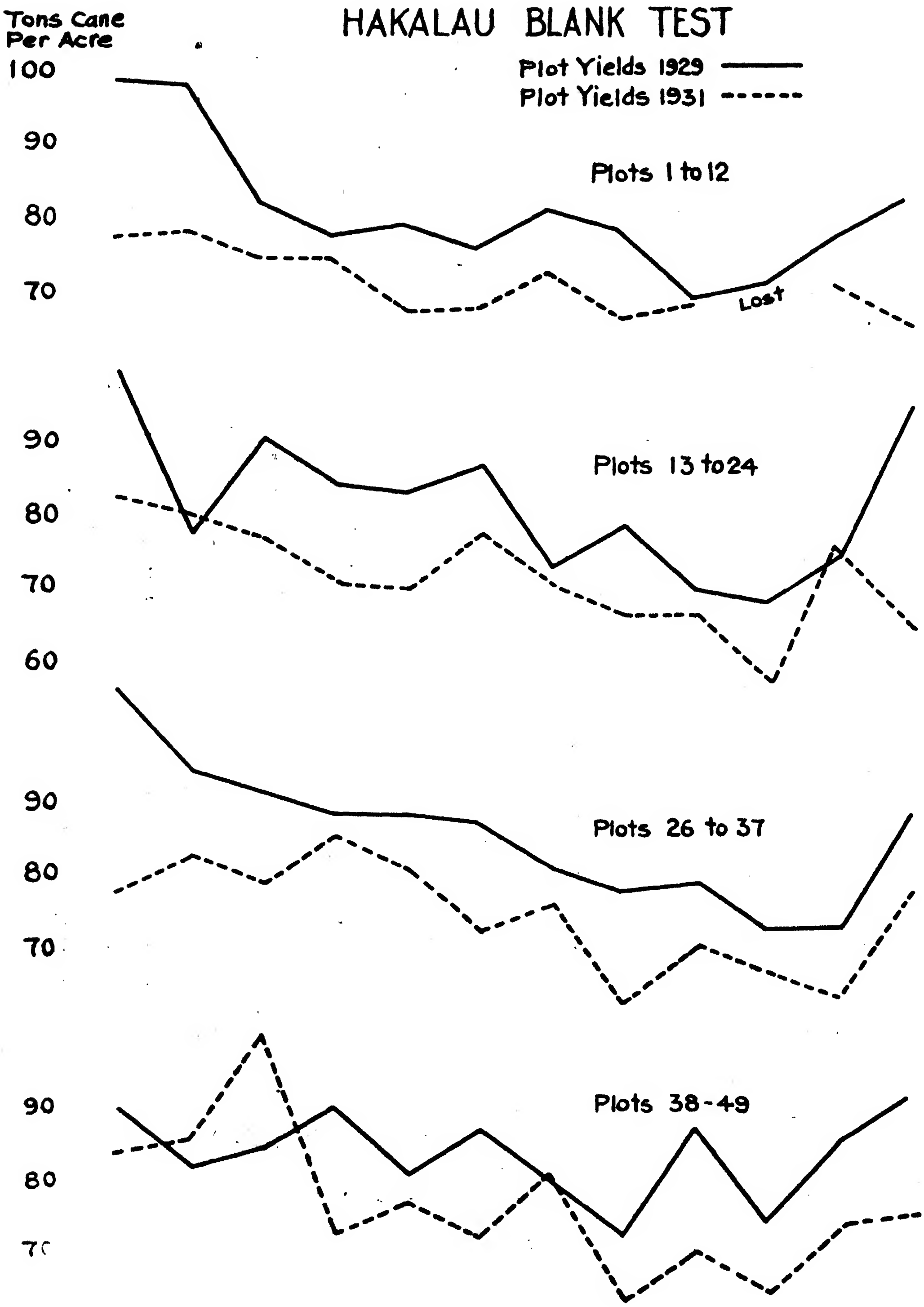

Tons Cane
Per Acre
HAKALAU BLANK TEST
Plot Yields 1929
Plot Yields 1931
100
90
80
70
Plots 1 to 12
Lost
90
80
70
60
Plots 13 to 24
90
80
70
Plots 26 to 37
90
80
Plots 38-49

Fig. 1.

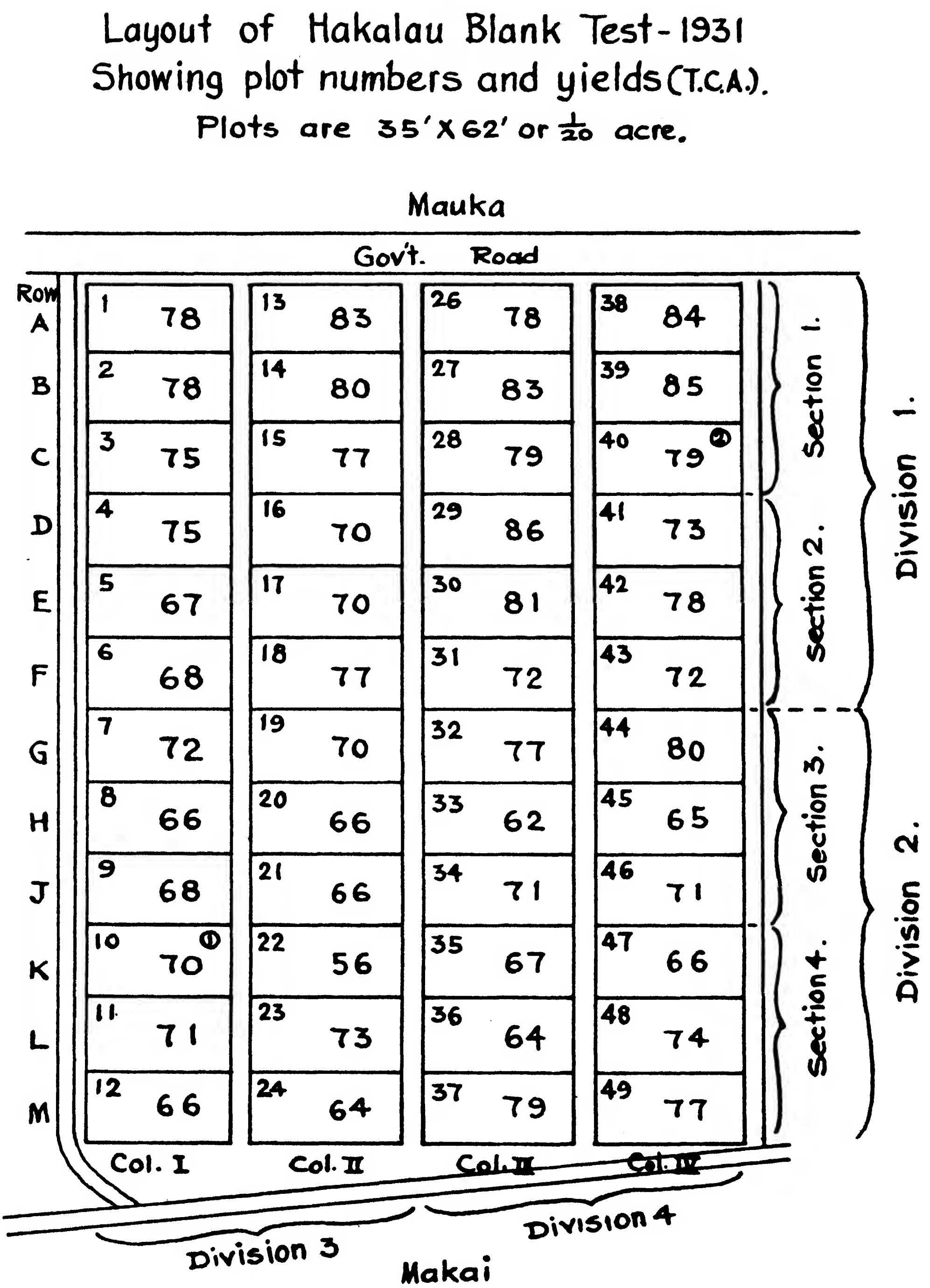


Fig. 2.

The method of dividing the area into segments for this study is shown to assist in identifying references to the various groups that are compared.

(1) The yield of this plot was lost. For this study it has been assumed as the average of the two plots on either side.

(2) The reported yield of this plot, 102 tons, is obviously in error. For this study it has been assumed as the average of the plots which adjoin it.

Table I

Summary of Individual Studies

Location or Identity of Plots Used (*)	Size of Plots	Average Yield Per Cent	C. V. or Per Cent S. D.	Number of Plots	Per Cent PEm
Sec. 1	35′ x 62′	80	3.88	12	0.76
Sec. 2	"	74	7.56	12	1.47
Sec. 3	"	70	7.42	12	1.45
Sec. 4	"	69	9.27	12	1.80
Col. I	35′ x 62′	71	6.2	12	1.18
Col. II	"	71	10.6	12	2.06
Col. III	"	75	10.2	12	1.98
Col. IV	"	75	8.5	12	1.65
Div. 1	35′ x 124′	77	6.10	12	1.18
Div. 2	"	70	7.35	12	1.42
Div. 3	"	71	7.75	12	1.52
Div. 4	"	75	8.60	12	1.67
Div. 1	70′ x 62′	77	6.20	12	1.20
Div. 2	"	70	4.90	12	0.92
Div. 3	"	71	7.74	12	1.51
Div. 4	"	75	7.00	12	1.36
All	35′ x 248′	73	7.47	12	1.45
"	70′ x 124′	73	7.35	12	1.42
"	140′ x 62′	73	6.92	12	1.35
Div. 1	35′ x 62′	77	6.95	24	0.96
Secs. 2 and 3	"	72	8.02	24	1.10
Div. 2	"	69	8.38	24	1.15
Div. 3	35′ x 62′	71	8.53	24	1.17
Cols. II and III	"	73	10.55	24	1.45
Div. 4	"	75	9.20	24	1.26
All	35′ x 124′	73	8.50	24	1.20
"	70′ x 62′	73	7.77	24	1.07
Secs. 1, 2, and 3	35′ x 62′	75	8.45	36	0.95
Secs. 2, 3, and 4	"	71	8.52	36	0.96
Cols. I, II & III	35′ x 62′	72	9.42	36	1.06
Cols. II, III & IV	"	74	9.58	36	1.08
All	35′ x 62′	73	9.20	48	0.90
All	105′ x 124′	73	7.15	8	1.70
"	210′ x 62′	73	6.65	8	1.55
"	70′ x 248′	73	7.02	6	1.93
"	140′ x 124′	73	7.00	6	1.93
"	105′ x 248′	73	7.00	4	2.36
"	210′ x 124′	73	6.95	4	2.35
"	420′ x 62′	73	3.20	4	1.08
"	140′ x 248′	73	7.10	3	2.74
"	210′ x 248′	73	7.55	2	3.62
"	420′ x 124′	73	3.90	2	1.86

(*) See layout, Fig. 2.

Shape

The longer, narrow plots (35′x124′) in Divisions 1 and 3, are no more variable than the squarer plots (70′x62′) in these same divisions, but Divisions 2 and 4 carry indications which point to a greater similarity between the squarer plots.

There appears to be less variation on the flume side of the field than on the opposite side, but the spot variation of the center columns is confusing. The direction of greatest variation, however, is from the mauka to the makai end of the test area, and we would therefore expect greater similarity within the group of plots whose long axes extend in the direction of this greater variation and which are laid out (across the field) at right angles to it. That we do find this condition is evident from the fact that when we divide the whole area into the same number of various shaped plots of a similar acreage, we have coefficients of variation as shown in Table II.

Table II

Showing Coefficients of Variation for Plots of Various Shapes

	C. V.	No. of Plots	Area	Shape (Width x Length)	Description
A.	8.50	24	.1 ac.	35′ x 124′	Long plot axis at right angles to greatest variation.
	7.77	24	"	70′ x 62′	Long plot axis parallel to greatest variation.
B.	7.47	12	.2 ac	35′ x 248′	Long axis at right angles.
	7.35	12	"	70′ x 124′	" " " " "
	6.92	12	"	140′ x 62′	" " parallel.
C.	7.15	8	.3 ac	105′ x 124′	Long axis at right angles.
	6.65	8	"	210′ x 62′	" " parallel.
D.	7.02	6	.4 ac	70′ x 248′	Long axis at right angles.
	7.00	6	"	140 x 124′	" " parallel.
E.	7.00	4	.6 ac	105′ x 248′	Long axis at right angles.
	6.95	4	"	210′ x 124′	" " " " "
	3.20	4	"	420′ x 62′	" " parallel.
F.	7.55	2	1.2 ac	210′ x 248′	Long axis at right angles.
	3.90	2	"	420′ x 124′	" " parallel.

Size of Plot

Our interest in plot size, springs from a desire to learn how the uncontrolled variation that exists in field experiments can be lessened to an extent that will allow us to compare purposeful introduced variates under the greatest similarity of conditions. Will large plots or small plots give us this greater uniformity?

In Table III, there is presented a summary of the separate comparisons

that were made to determine how an increased plot size would affect the coefficient of variation of various groupings that might naturally be made in the test area. For each comparison, we have used the same number (12) of plots, and were one group of comparisons did not occupy the whole of the experimental field, we have averaged the C. V.'s for separate groups sufficient to cover the whole area. and presented this average with its probable error. Hence our figures should at least be indicative, since every plot in the test area is represented in the amount of C. V. listed for each grouping of various sized (and shaped) plots.

TABLE III

SHOWING COEFFICIENTS OF VARIATION FOR PLOTS OF VARIOUS SIZES

(All forty-eight plots used in each grouping; twelve units for each comparison)

Group	No. of Comparisons	Identity and Description	Size	C. V.
1	4	Single plots, in columns	.05 ac.	8.90 ±.20
2 (a)	2	Double plots, end to end, in columns	.1 ac	8.18 ±.29
2 (b)	2	Double plots, side by side, in columns	.1 ac	7.37 ±.25
3 (a)	1	Quadruple plots, end to end, total area	.2 ac	7.47
3 (b)	1	Quadruple plots, side by side, total area	.2 ac	6.92
3 (c)	1	Quadruple plots, in a 2x2 block, total area	.2 ac	7.35
4 (a)	2	Double plots, end to end, in sections	.1 ac	6.73 ±.42
4 (b)	2	Double plots, side by side, in sections	.1 ac	5.55 ±.44
5	4	Single plots, in sections	.05 ac	7.03 ±.74

Comparing the groupings that were made in the columns, we apparently have quite definite evidence that the variation within the groups of plots decreases as their size is increased. This same decrease with larger plot size is not so apparent from the C. V. of the groupings of the sections. Perhaps this is what we should expect to find, since we have already noted the greater variability within the columns than within the sections. The larger plot size has evidently smoothed out the greater differences and lessened their effect upon the variability of the individual plot yields.

Within an area which shows quite general uniformity, in so far as field conditions can be uniform, there seems nothing to be gained by increasing the plot size. The twenty-four single plots in Division I have a C. V. of 6.95. Increasing their size from 35'x62' to 35'x124' results in an increased C. V. for the twenty-four larger plots, to 8.5; increasing their size to 70'x62' also results in a larger coefficient of variation (7.77).

Specifically, we show in Table IV, eight instances taken from our data, in which twelve single-unit (35'x62') plots are first doubled and then quadrupled in size. The change in the coefficient of variation of these blocks of twelve plots, shows how the increase in the individual plot sizes has affected the variability within them. The many exceptions wherein the greater size has failed to reduce the coefficient of variation, make it necessary for us to be exceedingly cautious in recommending large plots for field experiments, without having rather definite knowledge of the field variation which exists in the area wherein the test is to be installed.

Table IV

Showing How an Increase in the Size of Plot May Affect the Coefficient of Variation

No. of Plots	Size	Location	C. V.	No. of Plots	Size	Location	C. V.
12	35'x'62	Column I	6.20	12	35'x62'	Section 1	3.88
12	35'x124'	Division 3	7.75*	12	35'x124'	Division 1	6.10*
12	35'x248'	All	7.47	12	35'x248'	All	7..47*
12	35'x62'	Column IV	8.50	12	35'x62'	Section 4	9.27
12	35'x124'	Division 4	8.60*	12	35'x124'	Division 2	7.35
12	35'x248'	All	7.47	12	35'x248'	All	7.47*
12	35'x62'	Column I	6.20	12	35'x62'	Section 1	3.88
12	70'x62'	Division 3	7.74*	12	70'x62'	Division 1	6.20*
12	140'x62'	All	6.92	12	140'x62'	All	6.92*
12	35'x62'	Column IV	8.50	12	35'x62'	Section 4	9.27
12	70'x62'	Division 4	7.00	12	70'x62'	Division 2	4.90
12	140'x62'	All	6.92	12	140'x62'	All	6.92*

* The increased size has also increased the variation in these cases.

Replication

The individual plot in a field experiment is a sample. It has become a common tendency to replicate our plot treatments and present the average yield of similarly grown samples for the guidance of plantation practices. It should become a more common practice to furnish a measure of the accuracy of such averages by furnishing the probable error of the mean (PEm) with any average which is so submitted.

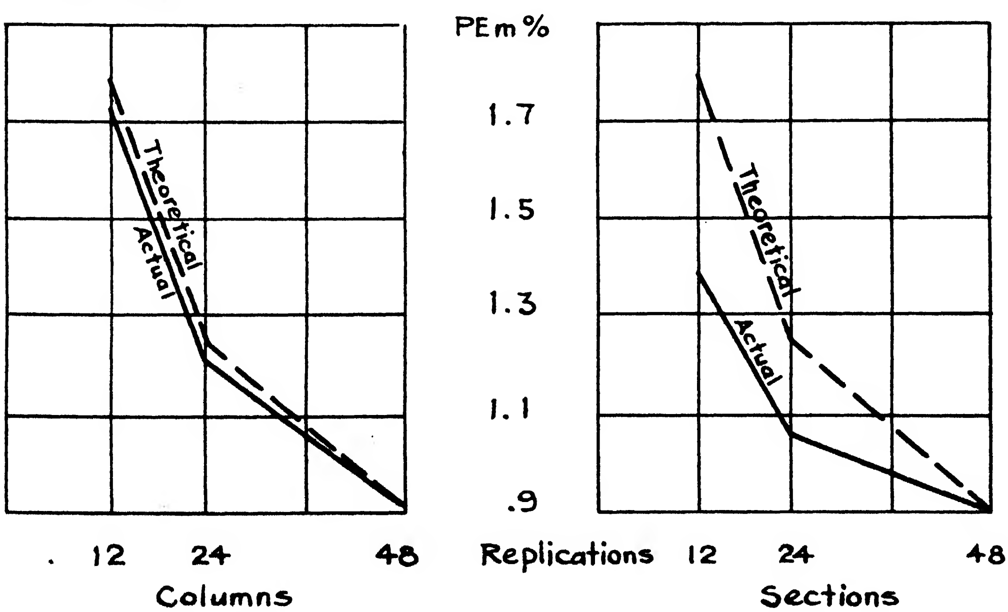


Fig. 3. Showing how an increase in the number of replications has reduced the probable error of the mean.

Our chief interest in the matter of plot replication lies in the fact that theoretically, a reduction in the probable error of a mean yield can be expected to occur in proportion to the square root of the number of plots or samples used. Hence an average yield from a larger number of samples should be a more reliable figure than an average yield from a smaller number. Considered as measures of reliability therefore, the lower PEm figures indicate greater accuracy.

The probable error for any single plot in this area is 6.21 per cent. In Table V and Fig. 3, we have presented the theoretically expected, and the actual reductions in error which have occurred as the number of plots was increased.

TABLE V

Plot Size	Identity	No. of Replications	Theoretical * PEm Per Cent	Actual PEm Per Cent
.05 ac.	Columns	12	1.81	1.72 ±.23
"	"	24	1.27	1.22 ±.03
"	"	48	.90	.90
"	Sections	12	1.81	1.37 ±.25
"	"	24	1.27	1.06 ±.06
"	"	48	.90	.90

* $\frac{\text{PEs}}{\sqrt{n}}$ or $\frac{6.21}{\sqrt{n}}$

More specifically, however, our interest lies in studying the effect on the PEm when a natural grouping is increased to provide more replications. We offer several instances of this sort in Table VI.

TABLE VI

SHOWING THE EFFECT ON THE PEM OF INCREASING THE TOTAL NUMBER OF ONE-TWENTIETH ACRE PLOTS, TO PROVIDE FOR MORE REPLICATIONS

Original 12 One-twentieth Acre Plots		Increased To 24 Plots		Increased To 36 Plots		Increased To 48 Plots	
Location	PEm%	Location	PEm%	Location	PEm%	Location	PEm%
1. Col. I	1.18	Col. I & II	1.17	Col. I, II & III	1.06	All 4 Col.	.90
2. Col. IV	1.65	Col. IV & III	1.26	Col. IV, III, II	1.08	All 4 Col.	.90
3. Sec. 4	1.80	Sec. 4 & 3	1.15	Sec. 4, 3, 2	.96	All 4 Sec.	.90
4. Sec. 1†	.76	Sec. 1 & 2	.96	Sec. 1, 2, 3	.95	All 4 Sec.	.90
5. (a) Sec. 3	1.45	Sec. 3 & 2	1.10	Sec. 3, 2, 1	.95	All 4 Sec.	.90
(b) "	1.45	Sec. 3 & 4	1.15	Sec. 2, 3, 4	.96	All 4 Sec.	.90
6. (a) Sec. 2	1.47	Sec. 2 & 3	1.10	Sec. 2, 3, 4	.96	All 4 Sec.	.90
(b) "	1.47	Sec. 2 & 1	.96	Sec. 3, 2, 1	.95	All 4 Sec.	.90
7. (a) Col. II	2.06	Col. II & III	1.45	Col. II, III & IV	1.08	All 4 Col.	.90
(b) "	2.06	Col. II & I	1.17	Col. III, II & I	1.06	All 4 Col.	.90
8. (a) Col. III	1.98	Col. III & II	1.45	Col. III, II & I	1.06	All 4 Col.	.90
(b) "	1.98	Col. III & IV	1.26	Col. II, III & IV	1.08	All 4 Col.	.90

PRACTICAL APPLICATION

In order to make a practical application of the data obtained in this study, let us assume that we are to test three variates and have selected this field upon which

† The increase in number of plots has not reduced the PEm in this case.

to install our layout. Starting with the row of plots at the government road, or at the flume, we have several natural alternatives which have been grouped in Tables VII and VIII to show how the relationships between size, shape and the number of replications which we might arbitrarily decide upon, would affect the probable error of the mean and hence the reliability of our average yield results.

Table VII

Showing the Relationship Between Size, Shape and Number of Replications, and How These Factors Would Affect the PEm Yield of Three Variates Installed, on the Hakalau Blank Test Layout, **from the Government Road.**

Location		Assumed Variates	Total Area Used	Plot Size	Plot Shape (WxL)	No. of Replications	Per Cent PEm
1. a.	Sec. 1	3	.6 ac.	.05 ac.	35′ x 62′	4	1.31
b.	Div. 1	3	1.2 ac.	.1 ac.	35′ x 124′	4	2.06
c.	All plots	3	2.4 ac.	.2 ac.	35′ x 248′	4	2.52
2. a.	Sec. 1	3	.6 ac.	.05 ac.	35′ x 62′	4	1.31
b.	Div. 1	3	1.2 ac.	.1 ac.	70′ x 62′	4	2.09
c.	All plots	3	2.4 ac.	.2 ac.	140′ x 62′	4	2.33
3. a.	Sec. 1 & 2	3	1.2 ac.	.05 ac.	35′ x 62′	8	1.66
b.	All plots	3	2.4 ac.	.1 ac.	35′ x 124′	8	2.01
c.	All plots	3	2.4 ac.	.1 ac.	70′ x 62′	8	1.85
4. a.	Sec. 1	3	.6 ac.	.05 ac.	35′ x 62′	4	1.31
b.	Sec. 1 & 2	3	1.2 ac.	.05 ac.	35′ x 62′	8	1.66
c.	Sec. 1, 2, 3	3	1.8 ac.	.05 ac.	35′ x 62′	12	1.65
d.	All 4 Sec.	3	2.4 ac.	.05 ac.	35′ x 62′	16	1.55

Table VIII

Showing the Relationship Between Size, Shape and Number of Replications, and How These Factors Would Affect the PEm Yield of Three Variates Installed on the Hakalau Blank Test Layout, **from the Flume.**

Location		Variates	Total Area Used	Plot Size	Plot Shape	No. of Replications	Per Cent PEm
1. a.	Col. I	3	.6 ac.	.05 ac.	35′ x 62′	4	2.09
b.	Div. 3	3	1.2 ac.	.1 ac.	35′ x 124′	4	2.61
c.	All plots	3	2.4 ac.	.2 ac.	35′ x 248′	4	2.52
2. a.	Col. I	3	.6 ac.	.05 ac.	35′ x 62′	4	2.09
b.	Div. 3	3	1.2 ac.	.1 ac.	70′ x 62′	4	2.60
c.	All plots	3	2.4 ac.	.2 ac.	140′ x 62′	4	2.33
3. a.	Col. I & II	3	1.2 ac.	.05 ac.	35′ x 62′	8	2.03
b.	All plots	3	2.4 ac.	.1 ac.	35′ x 124′	8	2.01
c.	All plots	3	2.4 ac.	.1 ac.	70′ x 62′	8	1.85
4. a.	Col. I	3	.6 ac.	.05 ac.	35′ x 62′	4	2.09
b.	Col. I & II	3	1.2 ac.	.05 ac.	35′ x 62′	8	2.03
c.	Col. I, II & III	3	1.8 ac.	.05 ac.	35′ x 62′	12	1.83
d.	All 4 Col.	3	2.4 ac.	.05 ac.	35′ x 62′	16	1.55

We have previously noted that the variation in any layout, starting from the government road, would be increased with any procedure, large plots or added replications, which would extend it into the more variable conditions at the makai end of the test area. The comparisons offered in Table VII amply illustrate this fact, and in the cases cited, *because we know of this variability*, we are not surprised that the reliability of our mean yields was not always increased (as indicated by a lowered PEm), where we had expected it to be.

From Table VIII, we note that where the extension of the total area for larger or more plots was across the direction of greatest variation, the increase in the number of replications was effective in slightly increasing the reliability of the average yield for the three assumed variates.

Summary

The uncontrolled variation within the area occupied by the Hakalau Blank Test has been determined and located.

The effect of altering the size and the shape of plots in order to secure greater similarity and uniformity for testing cane field problems has been studied.

The manner in which an increase in the number of plot replications, in a cane field, may or may not decrease the probable error and thus enhance the accuracy of their mean yield, has been pointed out.

Specific and practical applications of the statistical data have been made to illustrate how various changes can affect the reliability of average yields.

Generalization or recommendation, as to the best size or shape of plot, or with respect to the optimum number of replications that should be included in field tests from which the average yields of the various treatments are to be reported for plantation guidance, would be dangerous. *Only when we quite definitely know the nature and extent of the variation that exists in the area where we propose to install a field experiment, can we safely recommend that plan and layout which will give reliable guidance from average yields obtained.*

Some Mononchs of Hawaii

By Gertrude Cassidy

The soils of our cane fields—hitherto a biological terra incognita to most of us—give surprisingly interesting results when an attempt is made to determine their biological population.

Millions of inhabitants, many of microscopic dimensions, pursue their countless activities in the soil under our feet and collect in large and flourishing colonies around the roots of our sugar cane. Myriads of bacteria, protozoa, nematodes, annelid worms, insects and arachnids are present in our soils, and may be readily found upon microscopic examination.

Preliminary studies with relation to nematode infestation have led to the collection and preservation of representative soil samples from the cane-producing islands of Hawaii. Up to the present only a limited number of samples has been available and the species here recorded were obtained from a total of forty samples of soil.

A series of soil population counts have been undertaken to determine the nematode population of representative cane areas. These have been found to vary with the locality, type of soil, elevation and crop history, and result in numbers ranging anywhere from one to twenty billion nematodes per acre foot of soil. Of this vast population many genera and a large number of unrecorded species are present. An effort is being made to collect and identify these unrecorded species to enable us to interpret the significance of their presence around the roots of the cane. At the present time it is estimated that we have about 30 different genera, while the species range between 100 to 200 or more in number.

Formerly in our work it has been customary to divide the nematodes into three groups for convenience of description:

(1) The plant-destructive, spear-bearing nematodes which give rise to primary root damage.

(2) The plant-destructive nematodes which give rise to secondary root damage.

(3) The non-phytophagous nematodes.

Of these three groups, the first has received most of our attention and observations have been largely limited to the work of the root infesting Tylenchus. To date we are aware of five Tylenchus species in our sugar cane, the most widespread and active being *Tylenchus similis* which has been recognized in cane for over twenty years and is now found in more than half of our Hawaiian crop. Detailed root counts vary according to the severity of the infestation, the maximum count at present being 2532 Tylenchus nemas per linear inch of cane root.

Fig. 1. *Tylenchus similis*, adults, larvae and eggs as they appear upon dissecting an infested cane root. In this case one linear inch of infested root (P. O. J. 36 plant cane) was found to contain 2532 nemas. Photograph by C. W. Carpenter.

The following photographs (Figs. 2-3) demonstrate the differences in development noted in two sugar cane seedlings of the same variety and age. Fig. 2 represents a check seedling grown in soil sterilized by heating; Fig. 3, a Tylenchus-infested seedling grown under identical conditions and photographed 60 days after making the nematode inoculation.

Further studies are to be made to determine what part, if any, of the root damage is caused by organisms associated with the nematodes, and to ascertain, if possible, to what extent the activities of Tylenchus are influenced by the sterilization of the soil.

In general characters the two cane photographs (Figs. 2 and 3) resemble those of the Tylenchus-infested coffee plant, together with the check plant, illustrated in Fig. 4, which were the result of observations of Tylenchus damage in coffee, made by Dr. W. Bally, Proefstation, Malang, Java.

While all three groups are of importance in their relation to sugar cane, it was considered appropriate at this stage to devote some time to the study and identification of certain members of the third group—the non-phytophagous nematodes.

This group includes the predacious genus Mononchus (Bastian 1866) and it is with these nematodes that we are primarily concerned. For many years Mononchus, together with other genera found intimately associated with growing roots, was accepted as a plant-injurious nematode. This assumption was a natural one owing to the fact that specimens were seldom, ~~if~~ ever, observed alive so that their feeding habits did not come under observation. Through the researches of Cobb Steiner, Menzel and Heinly, this view has been disproved, and it is now an established fact that Mononchus is non-phytophagous and that, by reason of its predacious habit, it must be considered as a favorable factor in nematode control.

Fig. 2. Cane seedling (D 1135 x H 456) aged 4½ months. Control plant.

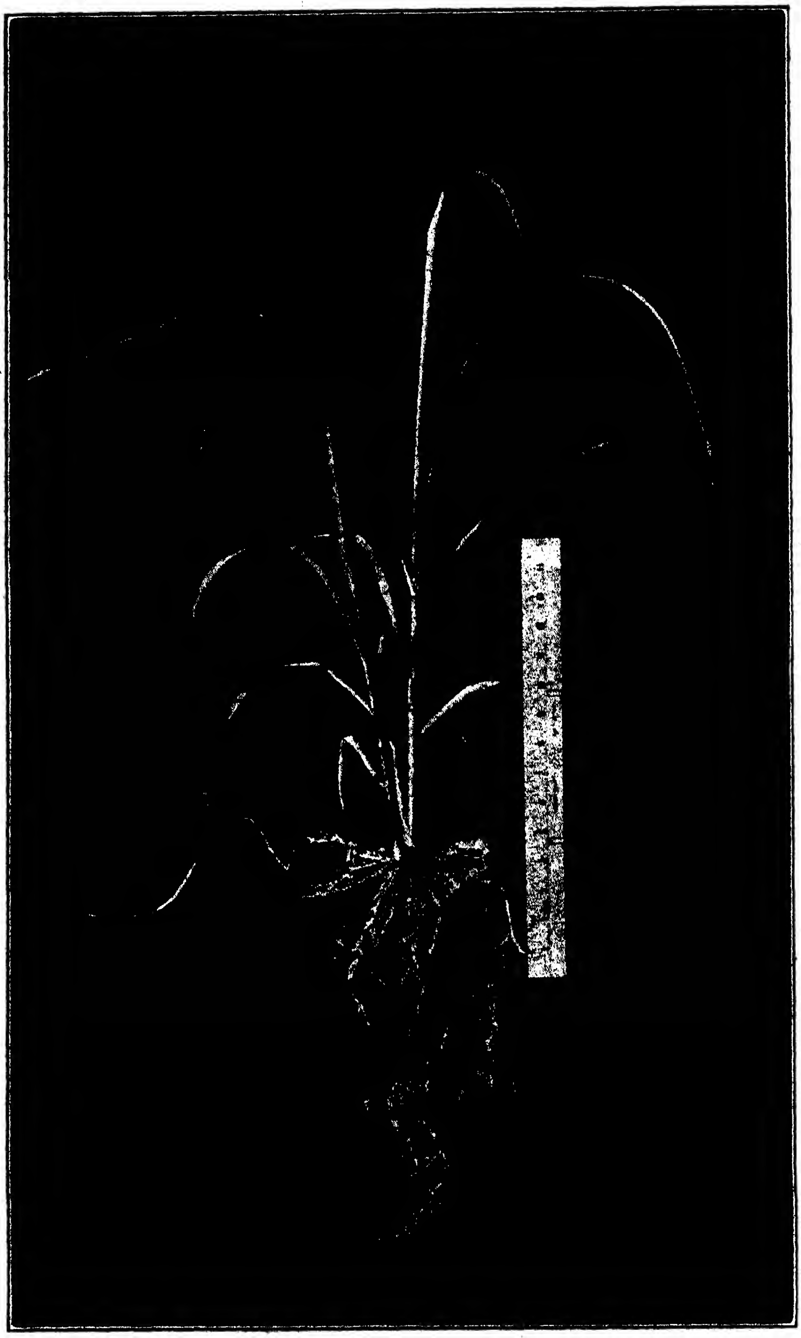


Fig. 3. Cane seedling (D 1135 x H 456) aged 4½ months, inoculated with a culture of *Tylenchus similis*. Inoculation period 60 days.

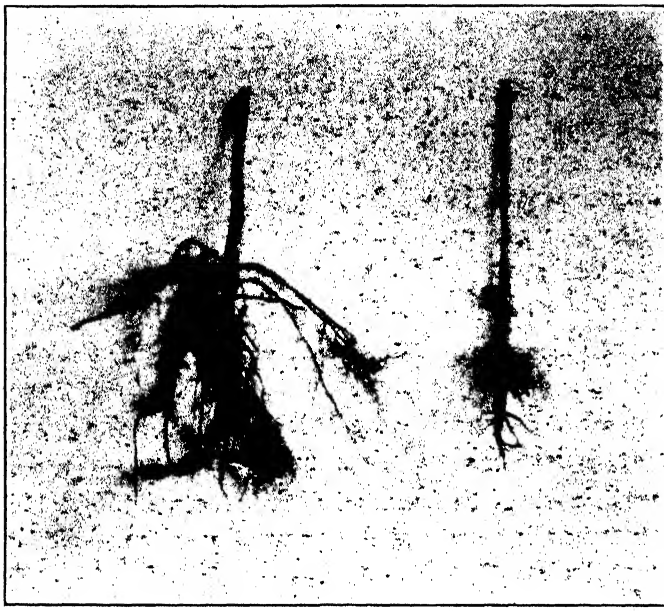


Fig. 4. Effects of Tylenchus in coffee plants. (Malang, Java.) Control plant on left. Nematode-infested plant on right. Photograph by courtesy of Dr. W. Bally, Proefstation Malang.

Soil examinations conducted during the past year show that certain species of Mononchus are present in the cane fields of Oahu, Hawaii, Maui and Kauai. The percentage population varies enormously with the location and as yet generalizations cannot be made as to the incidence of Mononchus in the field. From the limited number of examinations already completed it would appear that Mononchus is present in about 50 per cent of the cane fields. The population presents a wide range of difference in the various locations—in some only an occasional specimen being present, while in others, the counts rise to millions of Mononchus per acre.

The distribution of identified Mononchus species up to the present time is as follows:

Oahu—

Mononchus brachylaimus, Cobb, 1917.
Mononchus brachyuris, Bütschlii, 1873.
Mononchus lacustris, Cobb, 1915.
Mononchus longicaudatus, Cobb, 1893.
Mononchus hawaiiensis n. sp.
Mononchus papillatus, Bastian, 1866.
Mononchus sigmaturus, Cobb, 1917.

Hawaii—

Mononchus brachylaimus, Cobb, 1917.
Mononchus brachyuris, Bütschlii, 1873.
Mononchus index, Cobb, 1907.
Mononchus longicaudatus, Cobb, 1893.
Mononchus parvus, de Man, 1879.

Maui—

Mononchus brachyuris, Bütschlii, 1873.
Mononchus cobbi, n. sp..
Mononchus lacustris, Cobb, 1915.
Mononchus muscorum (Dujardin), Bastian, 1866.
Mononchus papillatus. Bastian, 1866.
Mononchus parvus, de Man, 1879.

Kauai—

Mononchus lacustris, Cobb, 1915.
Mononchus papillatus. Bastian, 1866.

This list of species is encouraging as it includes several of the most voracious and therefore most desirable Mononchus species known.

The experimental work of Steiner and Heinly, completed in 1922, proved conclusively that Mononchus is a natural factor worthy of consideration in the problem of nematode control.

The species cultivated by these workers was *Mononchus papillatus*, a cosmopolitan species well known for its voracity. This species is well established in certain localities of Oahu, Maui and Kauai and so the experimental findings of Steiner and Heinly may be utilized in our interest.

Laboratory cultures were made by these workers and observed over a period of several months (December-May). Various culture media were employed but finally it was found that the most favorable conditions were produced when a mixture of soil and water was used.

During this time the feeding habits of *Mononchus papillatus* were closely watched and one individual of this species was observed over a period of 12 weeks to devour a total of 1332 nematodes.

On this subject Steiner and Heinly report as follows:

Our records showed that the number of nematodes killed daily increased as the mononch developed, beginning with one or two destroyed during the third or fourth day of larval life, and attaining a maximal number of sixty-five. In one case as many as eighty-three *Heterodera radicicola* were killed (either swallowed wholly or partly sucked out) by one mononch in one day. The largest amount of food was consumed at the time the maximal number of eggs was produced, and then it decreased during the senile stage of life. During a lifetime of about twelve weeks one animal killed 1332 nematodes. We are certain that this number may be very much larger under natural conditions. It was also observed that during the moulting periods fewer nematodes were killed and for a period of one or two days none at all, with a decided increase after the moult. . . .

Judging from the behavior of *M. papillatus*, the organs of touch were probably the only ones used while hunting for food. The nema moved through the medium, continually searching its surroundings by moving the head end in all possible directions. The head end contains the chief organs of touch, as well as those for chemical perception. After long observations, we came to the conclusion that *M. papillatus* was not able to find its prey at long distance, and the use of the sense organs of touch seemed to be its chief method of locating food. We could therefore confirm statements made by Menzel about this matter.

As soon as the head end of a mononch came into contact with its prey, it grasped it tightly. By a sucking movement, probably of the oesophageal muscles, the head was fixed

to the prey. The nematode caught by the mononch naturally made most violent efforts to get free, and often the mononch was shaken and dragged along. But it held on tightly and soon its tooth and other mouth parts began to work. By a sucking movement of the oesophagus and mouth cavity, the mononch became more firmly fixed to its prey, when the tooth located on the dorsal wall was protruded and produced an opening in the skin of the victim. Then a stronger (or further) sucking action was exerted by the mononch and the tooth came back to its normal position. The whole oesophagus came often into action and moved forward and backward with the intestine, the whole body going through the same movements; first the body fluid of the prey was sucked out, and as this happened its body became shrunken. Very often the mononch was satisfied with this, and set free its prey, which died shortly afterwards. . . .

MONONCHUS PAPILLATUS AS A FACTOR IN FIGHTING NEMATODE PESTS

The foregoing experimental results show conclusively the predatory nature of *Mononchus papillatus*. From our experiments, and from observations made by other investigators, all kinds of nematode species, and Rotifers, Naididae (small Oligochaetes), etc., are taken as food. *Heterodera radicicola* is acceptable in large numbers, and we were able to rear *M. papillatus* by feeding this form of plant-injurious nema exclusively. The same thing happens in the soil and there is no doubt but that mononchs live there in about the same way as in our cultures. Undoubtedly this predatory nema when present kills *Heterodera* and other injurious forms in soil planted with crops. It is therefore extremely useful and its propagation should be encouraged. Under some conditions this form perhaps completely controls *Heterodera* and similar plant-injurious species. Why should this not become the case in our infested fields? Further investigations should be started along these lines.

Once in the roots, *Heterodera* and other such root-parasites are probably protected against the predatory mononchs, but when moving freely in the soil during larval life, they may be destroyed in large numbers and we are convinced that under favorable conditions *Mononchus* is able partially, perhaps completely to control some of these destructive forms. In order to advance any further along this line, it is absolutely necessary to have a knowledge of the nematode population of different kinds of soil, of the relationships that exist between these forms and other members of the community of living forms that exist there, and of their relationships to other nematode species.

THE SOIL, ITS LIFE AND THE NUMBER OF NEMATODES, ESPECIALLY OF PREDATORY FORMS THEREIN

Our knowledge of life in the soil, especially of microscopic life there, is still very restricted. We know very little about the relationships that exist between the living components of the soil, and often we do not even know these components. Certainly soil fertility does not depend entirely upon its chemical, colloidal and physical nature, but also and probably largely, upon the animal and plant life therein. The importance of soil bacteria is already known and there exists a close relationship between these bacteria and the nematode population, as a large number of nemas are bacteria consumers. Investigations carried on throughout more recent years have definitely proved that the soil contains an enormous number of nematodes, and that, next to bacteria, they form probably the largest constituent element in subterranean life.

Preliminary Observations on Cultured Mononchs

While it has not yet been possible to undertake detailed laboratory experiments with the Hawaiian species, preliminary observations have been made on two species (*Mononchus sigmaturus* and *Mononchus brachylaimus*) incidental to the collection and identification of the Hawaiian nemas:

(A). *Mononchus sigmaturus* was selected for observation as this is the species most commonly found in the cane fields of Oahu and a supply of fresh material was readily available. Cultures were prepared in (1) sterile water, (2) tap water, and (3) tap water and soil, and were kept in a moist chamber and the media changed daily.

After 24 hours culture (1) showed that ten *Mononchus sigmaturus* had devoured only eight of the nematodes supplied. The eight nemas which had been devoured were specimens of *Tylenchus similis* and *Heterodera radicicola.* The nemas which had escaped the Mononchus were very actively moving Rhabditis species. It was concluded from this and later observations that such forms as these escape the slower moving *Mononchus sigmaturus* by reason of the amazing rapidity of movement which certain Rhabditis species exhibit.

The *Mononchus sigmaturus* specimens did not appear to be favorably situated and were consistently sluggish in their movements from the first day of culture.

Never more than one or two victims were devoured within 24 hours by one of these *Mononchus sigmaturus* specimens and after the fourth day in culture the mononchs were outstretched and motionless and did not revive. The specimens were watched carefully but no eggs were deposited by this species during captivity.

Cultures (2) made in tap water, and (3) made of soil and water proved wholly unsatisfactory with this species. Within 24 hours heavy bacterial infection had occurred and further observations could not be made as the infected nematodes remained outstretched and could not be revived.

(B). A number of specimens of *Mononchus brachylaimus* were obtained from cane fields in Hawaii and used in culture for laboratory observation.

Cultures were made in (1) sterile water, (2) tap water, and (3) tap water and soil, and were kept in a moist chamber at room temperature and changed daily.

It was found that *Mononchus brachylaimus* responded equally satisfactorily to all three media and appeared highly resistant to bacterial contamination.

During the first 3-5 days of their captivity, specimens of *Mononchus brachylaimus* were noted to be extremely active and to attack and devour numbers of the nematodes added to the culture for their consumption.

Gradually they became more sluggish in their movements and would remain inert for long periods until transferred to a fresh medium 24 hours later. The number of nematodes devoured by *Mononchus brachylaimus* under these conditions was found to vary quite considerably.

At the beginning of cultivation, the mononchs were actively moving and in excellent condition. A number of observations were made to determine the daily quota of nematodes consumed by these mononchs but no definite estimate was arrived at.

It appeared that the voracity of the mononchs was appreciably influenced by their environment, and the abnormality of the situation in which they found themselves was amply demonstrated by their unfavorable reaction.

For instance, one culture of ten *Mononchus brachylaimus* observed to devour nematodes at the rate of ten per hour, was soon reduced to a pitiful two or three victims daily. As their appetite decreased so also did their other activities and

after a few days the cultured mononchs could be seen lying idly, regardless of the tempting food supplies at their disposal.

Observations made over a period of 12 weeks on a water culture containing one male and one female *Mononchus brachylaimus*, serves to demonstrate the variability of the devouring capacity of these nematodes in captivity.

First day in culture	10 nemas devoured (Tylenchus and Heterodera)
Second day in culture	8 nemas devoured " "
Third day in culture	6 nemas devoured " "
Fourth day in culture	1 nema and 74 eggs devoured (Heterodera)
Fifth day in culture	50 eggs devoured (Heterodera)
Sixth day in culture	4 nemas devoured (Heterodera)

After the fourth week in the culture medium the nemas were inert and listless and utterly disinterested in the food supplied. At most, one or two nemas were eaten and most frequently none at all. After the seventy-first day the male *Mononchus brachylaimus* died and was removed. The female continued to live until the eightieth day when she died also.

Eggs were deposited during the first three days of captivity but after that period no further deposition was observed. The earlier manifestations of physical activity, voracity and egg deposition must be accepted as more closely approaching the normal than the later less active condition.

Judging from the unusually strong pharyngeal musculature and the fact that a large percentage of all examined specimens commonly contain portions of ingested nematodes, it would appear that we are dealing with a species of unquestioned voracity.

There are several points in favor of *Mononchus brachylaimus* as a desirable species for cultivation with a view to field distribution:

(1) *Mononchus brachylaimus* is especially desirable from the standpoint of the worker as it is readily distinguished and easy to handle by reason of its usually large size (3-4 mm.).

(2) *Mononchus brachylaimus* appears to be resistant to bacterial infection under ordinary cultural conditions.

(3) *Mononchus brachylaimus* is provided with particularly strong pharyngeal muscles which enable it to attack successfully a large variety of nemas and devour large numbers within a limited period of time.

This species is not content with small larval forms and has been observed to attack and destroy nematodes fully twice its own size.

(4) *Mononchus brachylaimus* is undoubtedly one of the most voracious of our predatory nematodes as a large percentage of all examined specimens are found to contain ingested remains of one or more phytophagous nematodes.

Apparently it is customary for this species to bolt its victims without much if any effort at mastication as victims swallowed in toto are frequently found outstretched in the lumen of the intestine.

(5) *Mononchus brachylaimus* together with several other nematode species possess a curious oily quality of the cuticle which enables them to float easily upon the surface of fluids.

This characteristic together with the large size of the species facilitates the collection of the material and could doubtless be utilized as an easy means of distribution in the cane irrigation canals should further experimental observation determine the advisability of cultural distribution on the plantations.

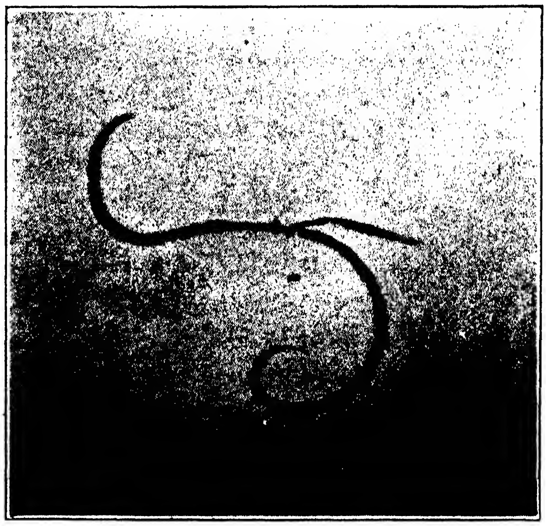


Fig. 5. *Mononchus brachylaimus* attacking a large spear-bearing nematode. Photograph by C. W. Carpenter.

Descriptions and Measurements of Mononchs Identified in the Hawaiian Islands

The eleven species here described have been identified from a limited number of soils and represent only adult forms. Wherever possible the average measurements of 6 females have been taken to give the percentage formula. Larval forms of other Mononchus species have been found in these Islands but identifications will be withheld until adults are available

Mononchus brachylaimus Cobb, 1917.

This species, originally described from Virginia, is now reported for the islands of Hawaii and Oahu, living in the soil of cane and pineapple fields. The average percentage measurements and description of the Hawaiian specimens are as follows:

Female—

			17.		16.		
2.7	7.	23.		61.		88.	3.7—4.4 mm.
2.2	2.5	2.5		3.1		1.8	

The truncate head is characteristic of the genus and is surmounted by 6 lips each bearing 4 papillae; the 24 papillae are arranged in two circles, an outer circle

of 18 papillae and an inner circle of 6 papillae. The lateral organs are duplex and are easily seen situated well forward in the anterior half of the pharynx. The oval pharynx is supported by 3 well developed pharyngeal ribs; the pharyngeal muscles of this species are unusually well developed (not shown in figure). The armature consists of 3 onchia: one rather small sharply pointed dorsal tooth is situated dorsally at the base of the pharynx opposed by 2 minute submedian, conical, forward-pointing toothlets. The cylindroid oesophagus widens slightly to receive the lower fourth of the pharynx; delicate cuticular papillae are seen at regular intervals in the oesophageal area, separated by a distance approximately measuring same as body width; the refractile lining measures about one-third the oesophageal diameter and is enclosed by the well developed radial muscles. The nerve ring is situated at about 7 per cent of the total length and is a broad band encircling the oesophagus. The lateral chords are finely granular and measure about one-third the body diameter. The intestine is separated from the oesophagus by a definite constriction and occupies three-fourths of the body width; the intestinal cells are definitely tessellated and the contents granular. The cardia is very plainly visible and is somewhat conical in outline. The vulva is very slightly elevated above the body surface; the vagina is short and placed at right angles to the body wall; the uteri are double joining the reflexed ovarian tubes which are placed upon the right side, and reflexed on the right also; the ovarian tubes contain approximately 14 ova; the ovum is thin-shelled and bluntly elongate measuring about one and one-half times the body width. The arcuate conoid tail tapers gradually to end bluntly with an unarmed spinneret; the tail shows 3 slender dorsal post anal papillae and one ventral papilla. The anus is conspicuous though not protruding. The rectum extends obliquely forwards and inwards and measures approximately the length of the anal body diameter.

Male—

The males are found quite as commonly as the female specimens. The percentage measurements are as follows:

2.6	7.	23.	54.	M 45.	90.	3.7—4.0 mm.
2.1	2.3	2.3		2.5	2.	

The paired spicula are arcuate and somewhat broad tapering slightly at the proximal and distal ends. At the anterior end of the spicula a filamentous prolongation is seen passing anteriorly and embracing four large sized rounded nucleated cells which lie anterior and dorsal to it. The accessory pieces are situated along the anal canal and broaden at the distal end forming a sharply bifurcate terminus. Anterior to the anus is a series of 17 supplementary nerve organs. Minute slender papillae may be seen on the dorsal surface of the cuticle occurring at intervals approximately equal to the body width. The testes are anterior and paired, one being slightly longer than the other (45 per cent and 54 per cent of the body length) and are filled with countless numbers of very small oval spermatozoa.

Spermatozoa of the same general appearance are to be found in the female receptaculum seminis (see Fig. 6).

All observations have been made with a 10 occular and a 2 mm. oil immersion objective. Fixative=Fleming's solution. Mounting medium=glycerine jelly.

Minor differences noted between the Hawaiian specimens and the Virginian specimens described by Cobb, 1917, are as follows:

Virginia	Hawaii
Female—One pair innervated papillae near the middle of the tail.	*Female*—Three slender dorsal post-anal papillae and one ventral papilla.
Conspicuous papillae in front of, and behind the vulva occupying a distance equal to 2 or 3 times the body diameter.	Slender threadlike papillae situated on the cuticular surface over the oesophageal area. Distance between papillae is approximately equal to the body width.
	Male—The testes are anterior and paired. (45 per cent and 54 per cent of the body length.)
Female—Total length—3.2 mm.	*Female*—Total length—3.7—4.4 mm.
Male—Total length—3.5 mm.	*Male*—Total length—3.7—4.0 mm.

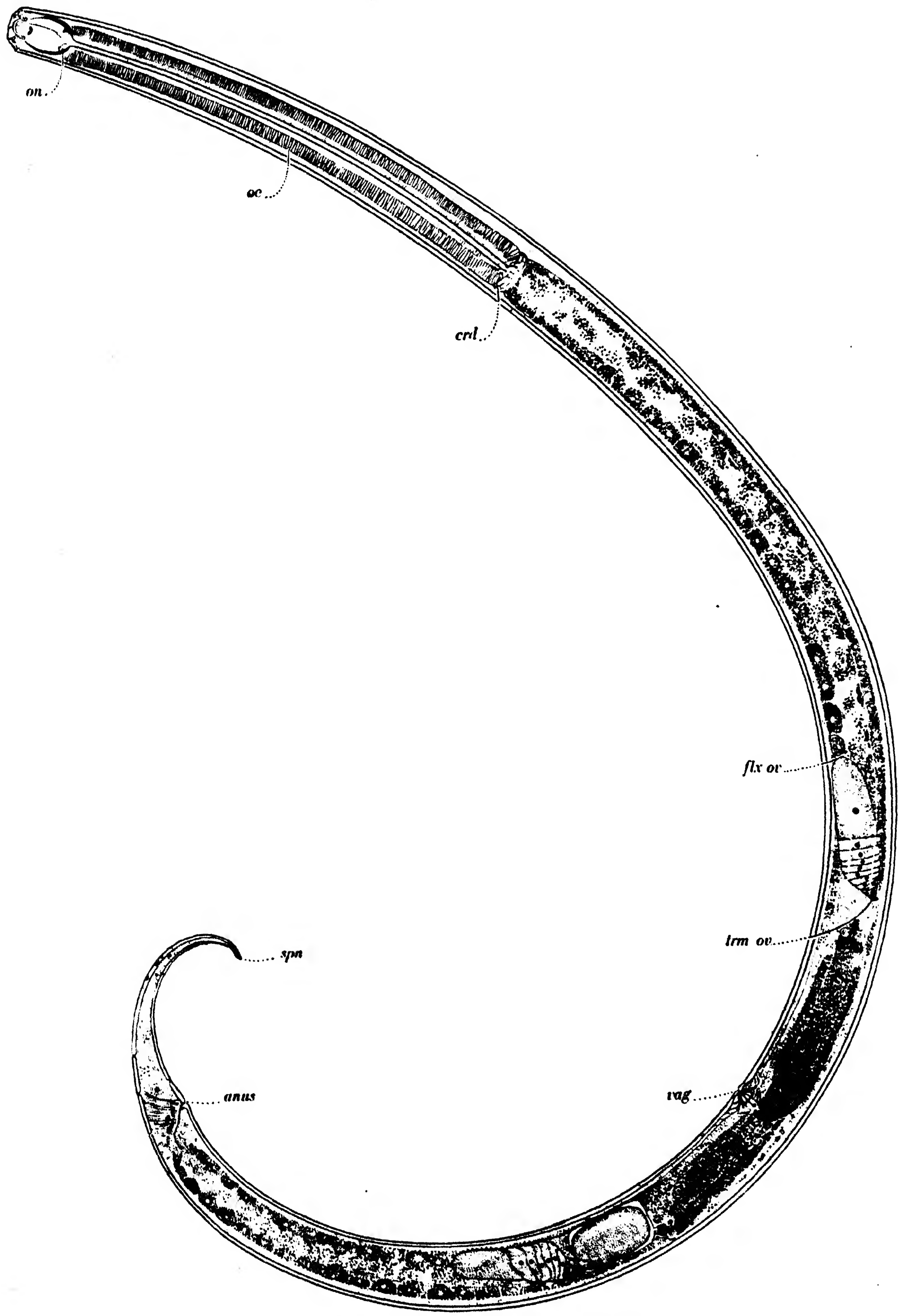


Fig. 6. **Mononchus brachylaimus.**
Adult female. *anus*—anus; *crd*—cardia; *flx ov*—flexure of ovarian tube; *oe*—oesophagus; *on*—dorsal tooth; *spn*—spinneret; *trm ov*—termination of ovarian tube; *vag*—vagina. (× 85).

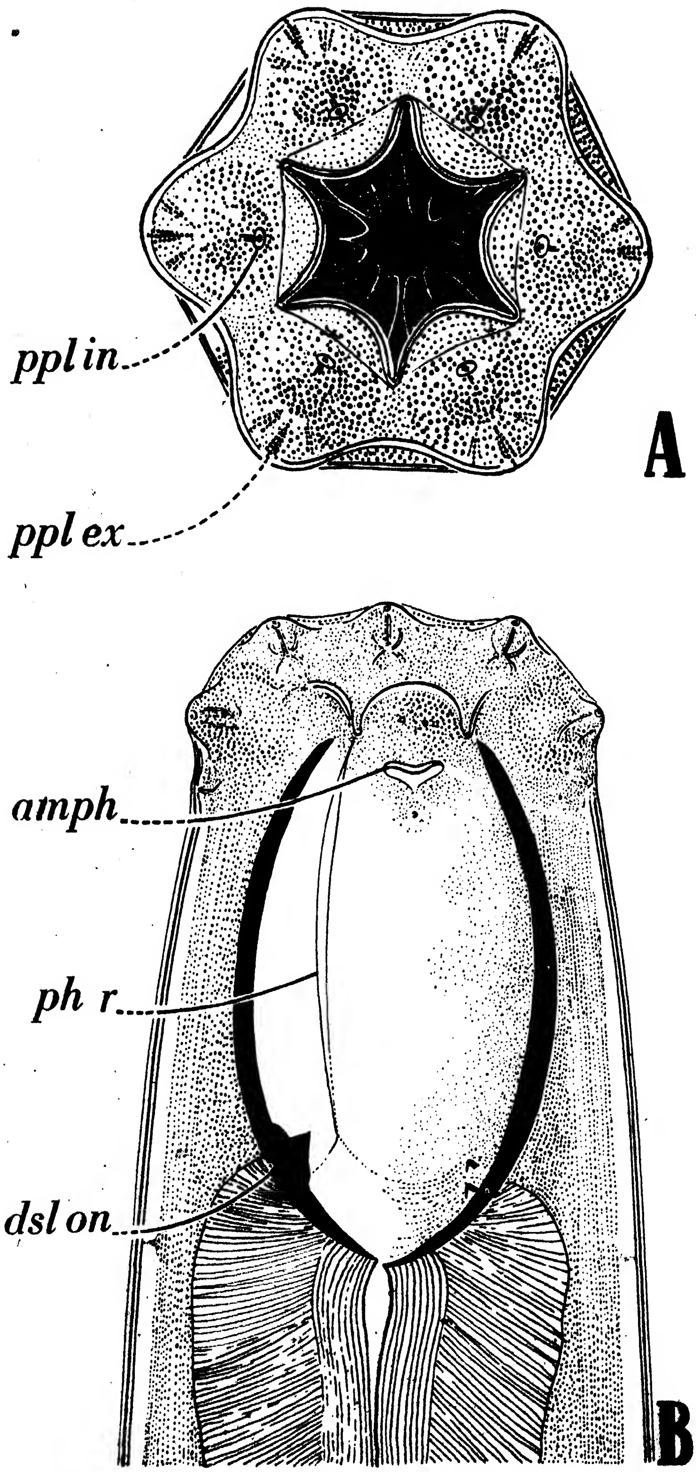


Fig. 7. **Mononchus brachylaimus.**

A. Head on end (adult female). *ppl ex*—outer papilla; *ppl in*—inner papilla.

B. Head end of young female. *amph*—amphid; *dsl on*—dorsal tooth; *ph r*—pharyngeal rib. (× 1000).

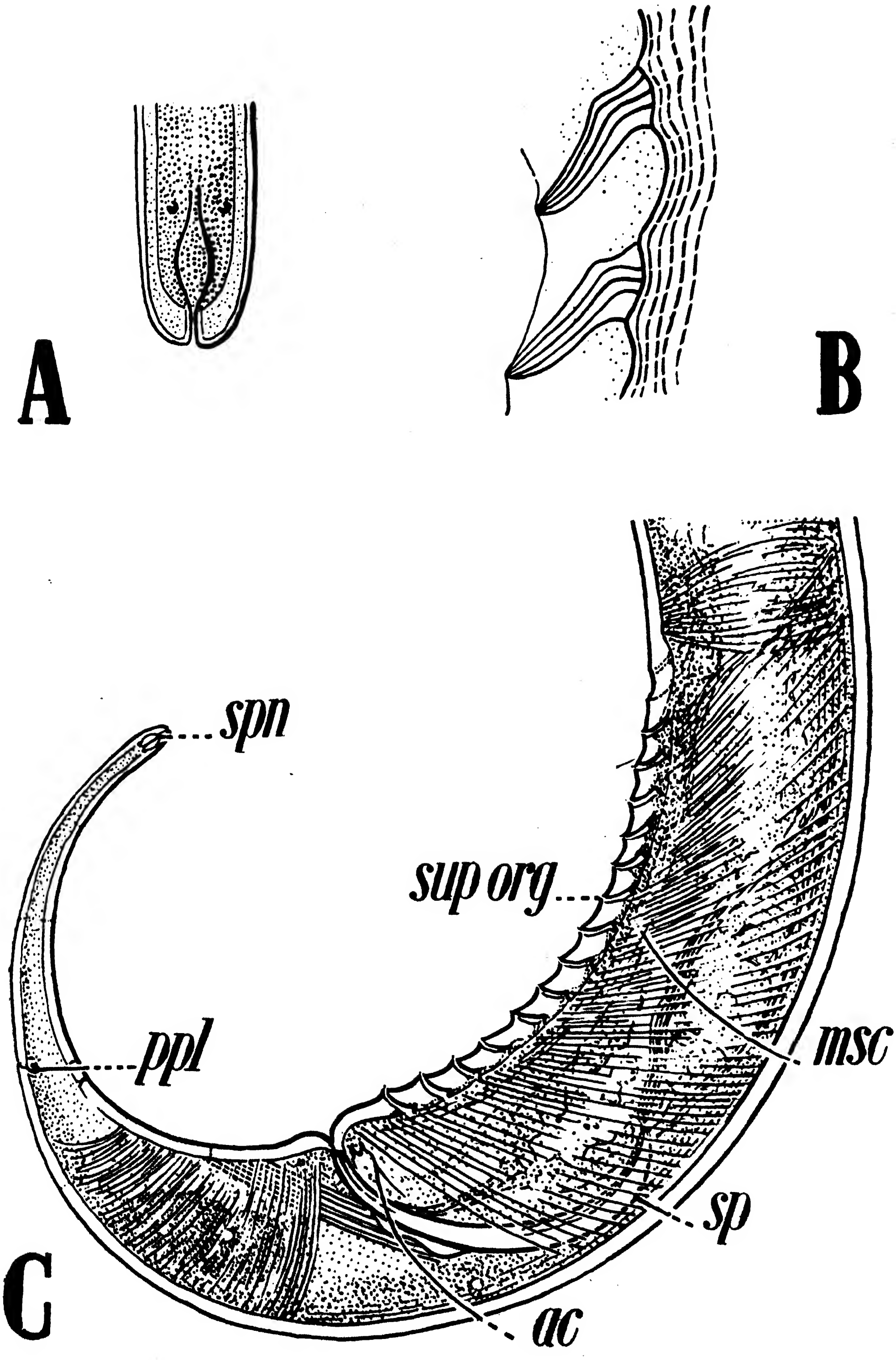


Fig. 8. **Mononchus brachylaimus.** Male.
A. Terminus of tail showing spinneret. (× 1400).
B. Ventral pre-anal body surface showing supplementary organs (× 1400).
C. Tail end of male. *ac*—accessory piece; *msc*—muscle fibres; *ppl*—post-anal dorsal papilla; *sp*—spicula: *spn*—spinneret; *sup org*—supplementary organ. (× 315).

Mononchus cobbi, n. sp.

This species is found in gravelly soils at high elevations on the island of Maui. The average percentage measurements and description are as follows:

			18.	18.	
3.1	9.	29.	68.	93.	
2.6	—	3.9	3.95	2.6	1.3 mm.

These average measurements were obtained from 4 adult females. In no case did the percentage measurement vary more than one per cent. The colorless cuticle shows definite transverse striations. The truncate head is surmounted by 6 lips each bearing 2 papillae. The lateral organs are large, occupying one-third of the width of the anterior third of the pharynx and are somewhat oval with a vaguely discernible rounded base. The pharynx is goblet-shaped and is armed with one rather small dorsal tooth situated midway on the dorsal wall. The cylindroid oesophagus has a refractile lining measuring one-third the width of the oesophageal diameter. The nerve ring is situated transversely across the oesophagus at 8-9 per cent of the body length. A slender pore is present on the ventral side below the nerve ring. The lateral chords are finely granular and measure one-third of the body diameter. The intestine is separated from the oesophagus by a definite constriction, presents a thick walled lumen, large tessellated cells and occupies three-fourths of the body width. The cardia is large and somewhat disc shaped. The vulva presents thick lips and is strongly supported, though not protrusile. The uteri are paired. The ovarian tubes are double and reflexed; the anterior ovarian tube is situated on the left side and contains about 8 ova arranged in single file; the posterior ovarian tube is situated on the right side and contains 10 ova arranged in single file. The arcuate tail is devoid of a spinneret; the anus is plainly marked though not protruding; the thick walled rectum extends obliquely forwards and measures approximately the width of the anal body diameter.

This species is considered highly voracious as a large percentage of all examined specimens was found to contain the ingested remains of one or more nematodes.

All observations have been made with a 2 mm. oil immersion objective and 10 occular. Fixative=mercuric chloride. Mounting media=glycerine jelly.

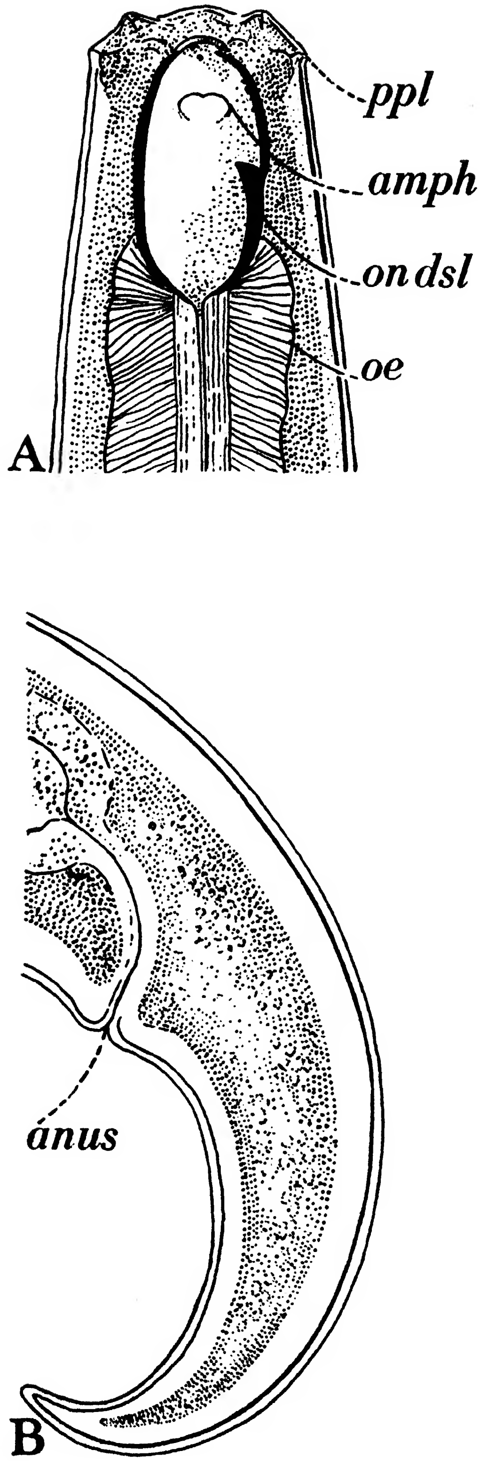


Fig. 9. Mononchus cobbi.

A. Head end of adult female. *amph*—amphid; *oe*—oesophagus; *on dsl*—dorsal tooth; *ppl*—papilla.

B. Tail end of adult female. *anus*—anus. (× 1020).

Mononchus parvus de Man, 1879.

Originally described in 1879, is reported from Holland and Germany. This species is found on Maui and Hawaii in sandy soils. The average percentage measurements and description for the Hawaiian specimens are as follows:

			15.		15.		
3.	8.5	29.		63.		93.	1 mm.
3.2	4.	4.		4.8		2.6	

The colorless cuticle shows definite striations. The truncate head is surmounted by 6 lips each bearing 2 papillae. The amphid is situated well forward in the ribbed pharynx and is a small transverse slit with slightly clubbed ends and a cupped base. The pharyngeal armature consists of one small dorsal tooth situated about midway in the pharynx; 2 refractile bodies, possibly minute rudimentary submedian toothlets, are faintly discernible at the extreme base of the pharynx. The nerve ring is situated at about 8 per cent of the body length; a small excretory pore is seen opposite the nerve ring. The muscular oesophagus is cylindrical, and possesses a refractile lining measuring about one-third of the oesophageal diameter. The nerve ring is poorly defined and is situated at 9 per cent of the total length. The granular lateral chords are indistinct but estimated to measure approximately one-third the body diameter. The very granular intestine is separated from the oesophagus by a definite constriction; the cells are faintly tessellated. The cardia is indistinct and rounded. The vulva is slightly raised above the body surface and has thick lips; the short vagina has thick walls; the uterus is double; the ovarian tubes are double and reflexed about half-way back to the vulva; each contains about six ova arranged in single file. The anterior ovarian tube is situated on the right side; the posterior ovarian tube is situated on the left side. The anus is not protruding; the short rectum measures approximately two-thirds of the anal body diameter; the tail is arcuate and devoid of a spinneret.

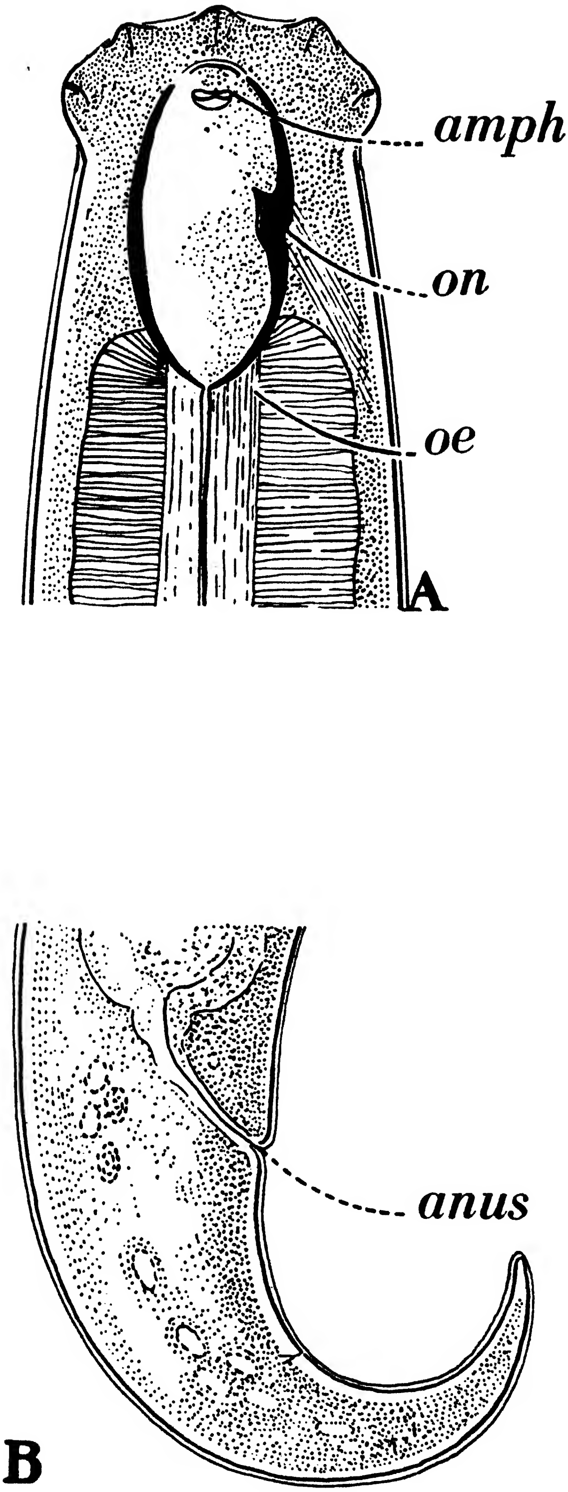


Fig. 10. **Mononchus parvus.**
A. Head end of adult female. *amph*—amphid; *oe*—oesophagus; *on*—dorsal tooth.
B. Tail end of adult female. *anus*—anus. (× 1200).

Mononchus sigmaturus Cobb, 1917.

This species has been reported on the mainland and Mexico and is found in abundance around the roots of sugar cane in certain localities on Oahu.

The average percentage measurements and description of the Hawaiian specimens are as follows:

			18.		18.		
2.3	10.	28.		64.		97.	1.21 mm.
2.	3.	3.		4.6		2.	

The truncate head has 6 well developed lips each bearing 2 papillae. The amphids are easily seen situated transversely to the long axis of the pharynx near the anterior end of the dorsal onchus. A large dorsal onchium is seen placed well forward in the pharynx; 2 small submedian onchia are present and 6 rows of small denticles arranged transversely in the area between the apices of the dorsal and submedian onchia. The nerve ring is difficult to distinguish, is cellular in character and placed at 10 per cent of the total length from the head end. The lateral chords measure one-fourth to one-third the body diameter and are finely granular. The cardiac constriction is plainly seen between the oesophagus and intestine. The intestinal cells are tessellated and the contents granular. The vulva is situated at 64 per cent of the total length and leads into the short straight vagina. The ovarian tubes are double and reflexed; the bluntly oval egg measures .0861 mm. x .042 mm.

The tail is characteristic as it suddenly bends ventrally and narrows behind the anus, forming a cylindroid terminus ending bluntly with an unarmed spinneret. The lips of the anus are very plainly seen though not protruding. An unusually wide dilatator ani muscle is present. The clear walled rectum stretches obliquely forwards and measures approximately the same as the anal body diameter. A slender ventral post-anal papilla is present situated between the ventral curve and the tip of the tail.

Males have not yet been found.

All observations made with a 10 occular and a 2 millimetre oil immersion objective. Fixative=mercuric chloride. Mounting medium=glycerine jelly.

A

B

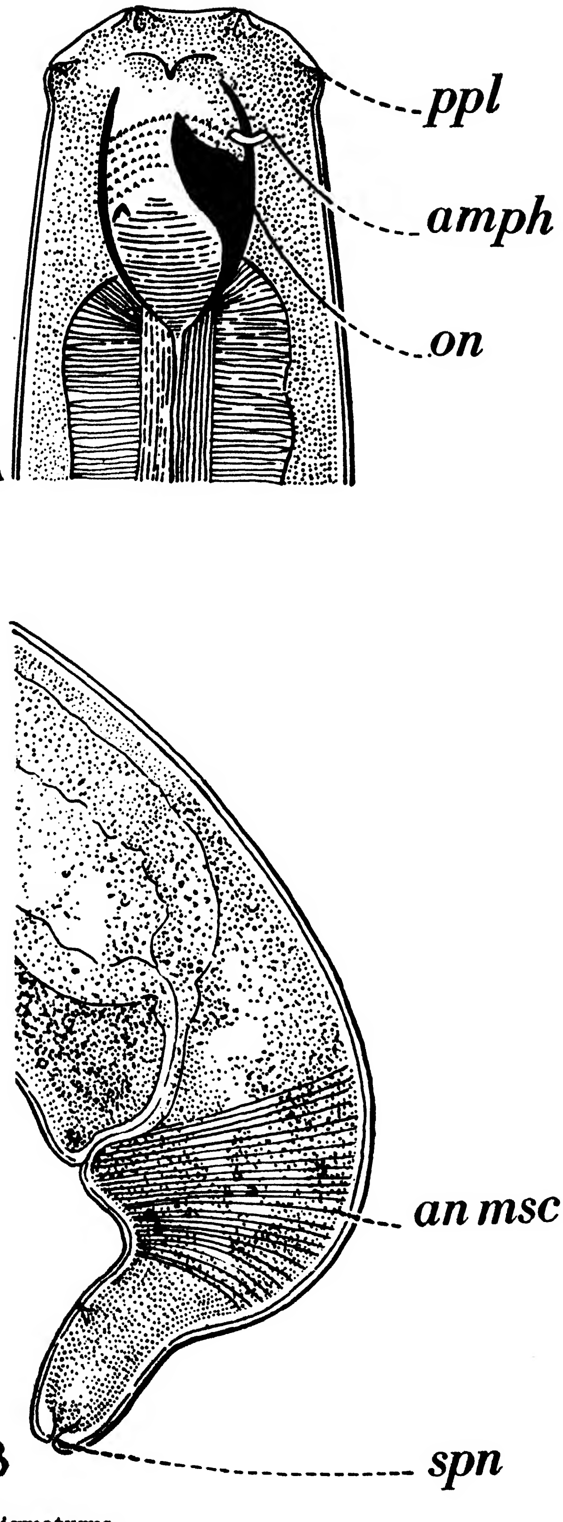


Fig. 11. **Mononchus sigmaturus.**
A. Head end of adult female. *amph*—amphid; *on*—dorsal tooth; *ppl*—papilla.
B. Tail end of adult female. *an msc*—anal muscle; *spn*—spinneret. (× 1100).

Mononchus hawaiiensis, n. sp.

This species is found on Oahu in soils rich in humus. The percentage measurements are as follows:

$$\frac{3.}{2.5}\text{———}\frac{9.}{3.}\text{———}\frac{28.}{3.}\text{———}{}^{15.}\frac{61.}{3.5}{}^{15.}\text{———}\frac{96.}{3.1}\quad 1\text{ mm.}$$

Very fine transverse cuticular striations may be seen under the highest power. The cylindroid neck is surmounted by a truncate head possessing 6 lips; each lip has 3 papillae (2 outer and 1 inner). The slit-like amphids are exceedingly difficult to define and are situated transversely in the pharynx opposite the apex of the dorsal tooth. Two pharyngeal ribs are seen. The armature consists of one very large dorsal tooth situated well forward in the pharynx, 5 or 6 transverse rows of very small denticles, and 2 small ventral submedian teeth situated at the base of the denticles on the ventral side.

The cylindroid oesophagus receives the lower fourth of the pharynx; the radial musculature becomes coarser in the posterior two-thirds; the refractile lining occupies one-fourth of the oesophageal diameter. The nerve ring is situated at about 9 per cent of the body length. The lateral chords are finely granular and measure one-third of the body width. The intestine is separated from the oesophagus by a definite constriction; the cardia is rounded and shallow; the intestinal cells are not tessellated and the contents are granular. The vulva has very thick lips and is slightly protruded above the body surface; the vagina is short; the uterus double; the ovarian tubes are double and reflexed about three-fourths the distance back to the vulva; the ovarian tubes contain about 8 developing ova. The arcuate tail is acutely bent ventrally a short distance behind the protruding anus. The tail narrows rapidly from the anus and is then cylindroid terminating bluntly in an unarmed spinneret. One ventral pre-anal papilla is present and 2 dorsa-sublateral papillae are situated just posterior to the anus.

All observations were made with a 2 mm. oil immersion objective and a 10 occular.

Fixative=mercuric chloride. Mounting medium=glycerine jelly.

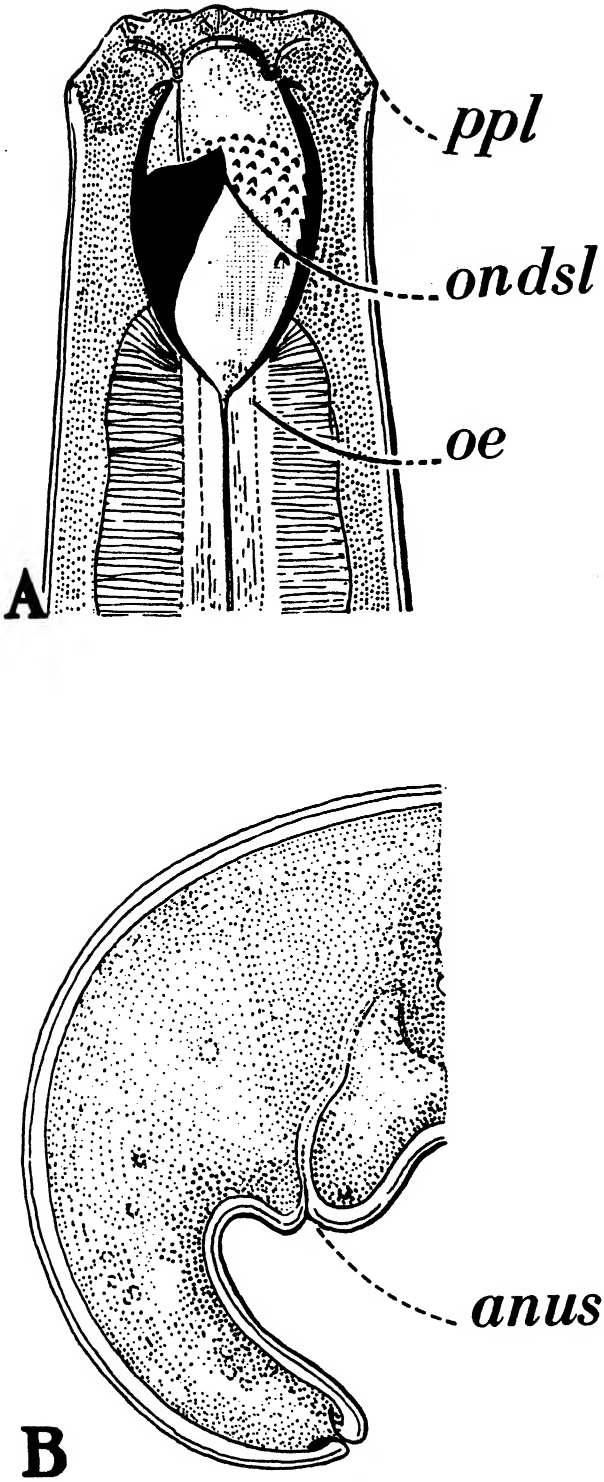


Fig. 12. **Mononchus hawaiiensis.**
A. Head end of adult female. *oe*—oesophagus; *on dsl*—dorsal tooth; *ppl*—papilla.
B. Tail end of adult female. *anus*—anus (X 1400).

Mononchus lacustris, Cobb, 1917.

This species already identified from Michigan, Panama and Florida is found around sugar cane on the islands of Oahu and Maui; also found in pineapple soils on Oahu and on Maui.

The average percentage measurements of the Hawaiian specimens are as follows:

$$\frac{2.5}{2.0}\quad\frac{9.}{4.}\quad\frac{28.}{4.}\quad\overset{12.}{}\quad\frac{64.}{4.}\quad\overset{12.}{}\quad\frac{95.}{2.5}\quad 1.3\text{–}2\ \text{mm.}$$

The cuticle shows slight transverse striations. The cylindroid neck is surmounted by the typical truncate head bearing 6 lips. The lateral organs are oval and cupped at the base, situated transversely to the long axis of the pharynx and placed slightly anterior to the apex of the dorsal tooth. One pharyngeal rib is noticeable in the goblet shaped pharynx. The floor of the pharynx shows transverse striae, especially noticeable at the base. The armature consists of one very large acutely pointed dorsal tooth situated in the anterior half of the pharynx; 2 smaller submedial teeth about the middle of the pharynx, and 6 rows of small denticles arranged transversely in the area between the tip of the dorsal tooth and the basal submedian teeth. The oesophagus is cylindroid with a refractile lining measuring one-third of the oesophageal diameter; the lumen is plainly visible, and the radial musculature well developed. The nerve ring is seen at a distance measuring approximately 9 per cent of the body length and is surrounded by cells. The lateral chords are granular and measure about one-third of the body width. The granular intestine occupies three-fourths of the body and shows faint tessellation. The cardia is broad and somewhat shallow but distinct. The vulva is unusually thick lipped but not protruding and is succeeded by a short vagina entering the double uteri. The ovarian tubes are on the right side, contain approximately 8 ova, and are reflexed about half-way back to the vulva (i.e., one-third of the total length). The egg measures about 1½ times the body width (0.294 x .0485 mm.). The arcuate tail is bluntly conoid. The anus is plainly seen though not protruding. There are 3 large post-anal glands situated in tandem which occupy the width of the body and extend from the rectum down towards the tail. The tail is blunt at the terminus and provided with an unarmed spinneret with a needle shaped valve.

Mounting medium=glycerine jelly. Fixative=bichloride of mercury.

The Hawaiian specimens (1.3-2 mm.) appear to be longer than those found in Michigan (1.1 mm.). This species closely resembles *Mononchus montanus* Thorne, 1924, *Mononchus parabrachyuris* Thorne, 1924, and *Mononchus polonicus* Stefanski, 1915.

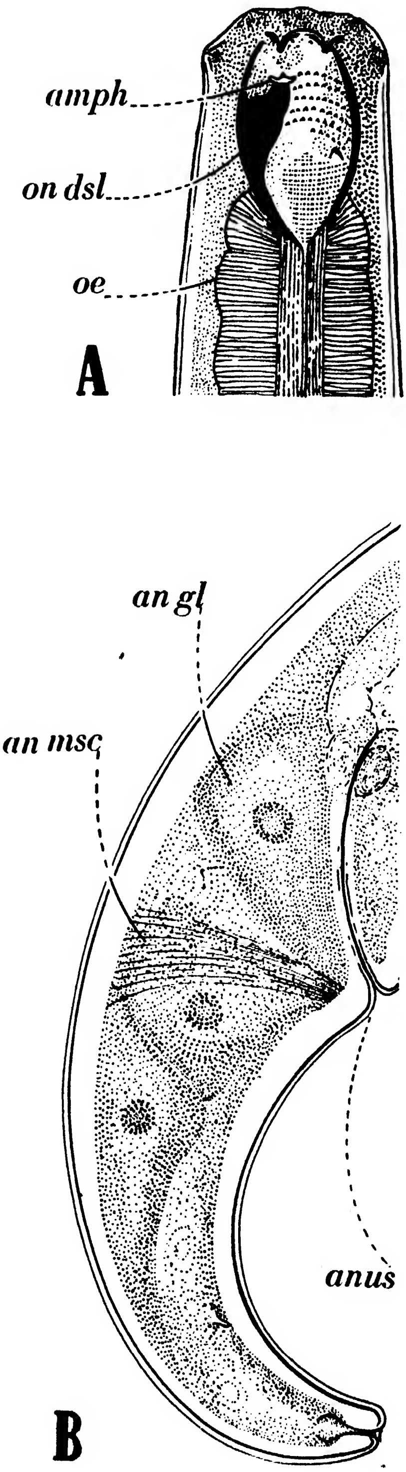


Fig. 13. **Mononchus lacustris.**

A. Head end of adult female. *amph*—amphid; *oe*—oesophagus; *on dsl*—dorsal tooth.

B. Tail end of adult female. *an gl*—anal gland; *an msc*—anal muscle; *anus*—anus. (× 750).

Mononchus muscorum (Dujardin) Bastian, 1866.

This is the oldest species of Mononchus known and has been reported from various parts of Europe and America. The Hawaiian specimens were found in gravelly soil on the slopes of Haleakala at an elevation between 7000-8000 ft.

The average measurements of the Hawaiian species are as follows:

$$\frac{2.3}{2.3}\quad\frac{7.5}{3.}\quad\frac{22.}{3.3}\quad\frac{\overset{21.}{60.}}{4.}\quad\frac{\overset{21.}{93.}}{2.8}\quad 1.8 \text{ mm.}$$

Definite transverse striations may be distinguished in the colorless cuticle. The truncate head is not set off and shows 6 lips provided with an inner and outer circle of papillae. The amphids are clearly seen situated transversely in the anterior half of the pharynx near the apex of the dorsal tooth. The ellipsoidal pharynx is about twice as long as it is wide and shows a well developed pharyngeal rib. The pharyngeal armature consists of a large dorsal tooth, the apex of which is well forward in the anterior half of the pharynx; and a ventral longitudinal rib bearing 14 sharp forward-pointing denticles. The muscular cylindroid oesophagus has a wide refractile lining. The nerve ring is situated at about 7.5 per cent of the total length; a slender pore is visible on the ventral surface opposite the nerve ring. The lateral chords are finely granular and measure about one-third of the body width. The oesophagus is separated from the intestine by a definite constriction; the rounded cardia is plainly visible. The intestinal cells are large and tessellated. The strongly supported vulva is not raised above the body contour; the short vagina extends across one-third of the body width; the uteri are double; the ovarian tubes are paired; the anterior ovarian tube lies on the left side; the posterior ovarian tube lies on the right side, both are reflexed to a distance about half-way back to the vulva; each tube contains approximately 10 ova arranged in single file.

The tail is arcuate and conoid; the anus is plainly visible though not protruding; the rectum extends obliquely forward, measuring about three-fourths of the anal body width. There is no spinneret.

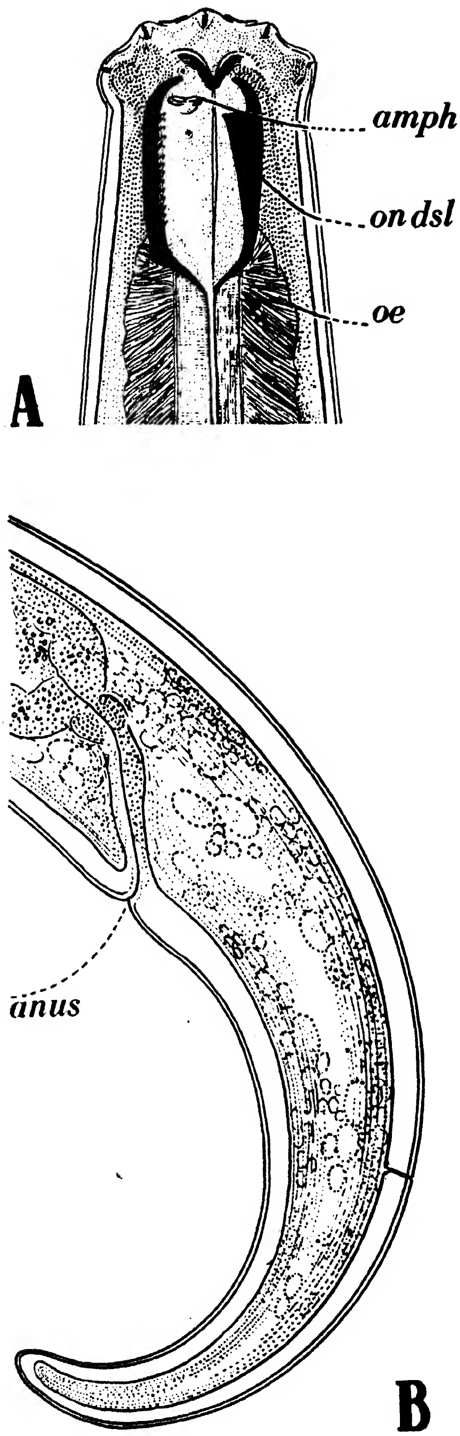


Fig. 14. **Mononchus muscorum.**
A. Head end of adult female. *amph*—amphid; *oe*—oesophagus; *on dsl*—dorsal tooth.
B. Tail end of adult female. *anus*—anus. (× 800).

The following four descriptions of Hawaiian specimens were made by Dr N. A. Cobb:

Mononchus longicaudatus, Cobb. (2)

$$\frac{2.3}{2.2} \quad \frac{7.}{3.1} \quad \frac{24.}{3.4} \quad \frac{54.5}{3.8} \quad \frac{87.5}{2.4} \quad 1.7\text{—}2.\ \text{mm.}$$

The colorless skin is composed of several layers easily distinguishable one from the other, the outer layer being of a chitinous nature and the inner layer composed of powerful-looking muscular tissue. The chitin is not resolvable into striae except with the highest powers. There are no hairs on the surface of the body. The nearly truncate head is continuous with the subcylindroid neck. There are no setae. Six lips arch themselves over the top of the pharynx and bear twelve papillae in two rows of six each, all these papillae being inconspicuous. The lateral organs are inconspicuous, transverse, short, arched slits a little in front of the middle of the pharynx. The species is eyeless. The pharynx and its armature are quite typical, the former being plainly triquetous and the latter consisting of a single dorsal tooth a trifle in front of the middle. There are no other teeth. Obscure markings resembling the teeth of a saw mill file exist on the walls of the pharynx opposite the dorsal tooth. The cylindroid oesophagus contains a thick conspicuous lining and is separated from the intestine by a conspicuous constriction which reduces the diameter to one-half that of the corresponding part of the body. The intestine becomes at once quite two-thirds as wide as the body. There is a distinct cardiac cavity in which the cardia can be plainly seen. The cells composing the intestine are conspicuously and regularly tessellated. The oblique rectum is equal in length to the anal body diameter. The longitudinal fields were not observed. The nerve-ring encircles the oesophagus squarely. The tail is conoid in the anterior half and cylindroid in the posterior half, being in this portion only about one-fourth to one-fifth as wide as at the base. The barely swollen terminus is armed with extremely inconspicuous papillae. The anus is depressed. The vulva, a conspicuous feature on account of the chitinous nature of the vaginal duct, is neither depressed nor raised. The sexual organs are double and are reflexed to near the vulva. They occupy a space equal to the length of the neck.

Habitat. About the roots of diseased cane near Hilo, island of Hawaii, August 20, 1905.

Mononchus longicaudatus has been identified in the soils of cane fields on Oahu, 1926-1931. This species has also been identified in the soils of pineapple fields on Oahu by Dr. H. R. Hagan, Associate Nematologist, Experiment Station of the Association of Hawaiian Pineapple Canners.

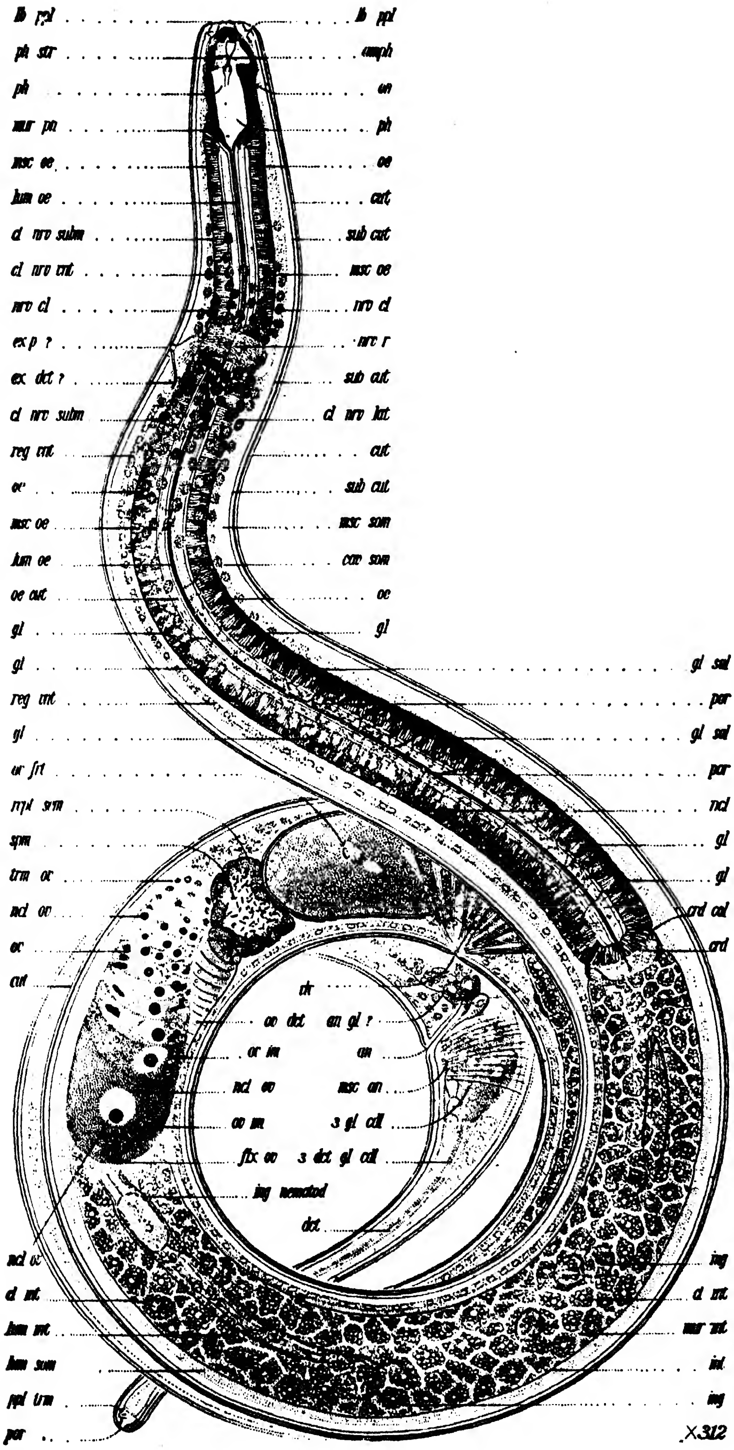


FIG. 2. — Female of a typical mononch, *Mononchus longicaudatus*, a syngonic form. This individual had been feasting on other nemas, the remains of which are shown inside the intestine. Only the anterior half of the sexual organs can be seen in the illustration; an entirely similar branch is hidden on account of the coiled attitude of the body. The lettering of the illustrations is similar throughout and is explained at the bottom of page 431. The anatomy and histology of various newly discovered features are shown:—

Œsophageal glands (*gl. sal.*), the pore through which the glands empty into the œsophagus (*por.*), syngonic sperm (*spm.*), formation of polar body (*ov. frt.*), ingested protozoon (*ing.*), etc.

Fig. 15. After Cobb.

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* Soil Science, 1917, Vol. III, p. 434.

Mononchus index n. sp. (2)

			15.		
2.1	8.8	30.	69.	95.6	.9 mm.
2.4	3.2	3.5	3.6	2.	

Even the highest powers failed to disclose any markings on the cuticle, the layers of which are comparatively thin. Throughout this description the details are drawn from specimens killed with osmic acid and then mounted in glycerine, hence it is possible that in the fresh condition, markings might be more apparent. There are no hairs on the surface of the body. The neck, which is unusually long, has nearly the same diameter throughout its length, but diminishes with more rapidity opposite the base of the pharynx to form the rather cylindrical truncate head, with a slightly expanded lip region. There are no cephalic setae. Each of the six lips bears two papillae, one on its inner margin, the other on its outer. It is doubtful whether these two papillae have precisely the same function, as they appear to differ somewhat in structure. Lateral organs are indicated by transverse markings bent backwards at the ends. These are opposite the middle of the dorsal tooth. In length they are about equal to half the width of the posterior portion of the pharynx, or about one-fifth the width of the head. There are no eyes. The pharynx is of the sort most commonly observed among the short-tailed species of the genus. The dorsal tooth, located near the middle of the pharynx, is rather massive and is opposed by about five rows of rasp-like teeth, the outer rows being more distinct than the inner. These are placed precisely opposite the point of the dorsal tooth. The pharynx is nearly half as wide as the head and about three times as deep as wide. There are no submedian teeth, the dorsal tooth being the sole occupant of the pharynx. The oesophagus is conoid in its general shape, being anteriorly about half and posteriorly about two-thirds as wide as the corresponding parts of the neck. Throughout its length, the massive lining is very plainly visible, occupying about one-fourth the optical section. The muscular markings are much more visible in the posterior half of the oesophagus than in the anterior half. The cardiac column is rather shallow but is a very distinct constriction. The cardia has a rather peculiar form. In optical section, the posterior contour is pointed, and it seems impossible to attribute this appearance to any shrinkage in the specimen. The intestine becomes at once four-fifths as wide as the body, and as the walls of the anterior portion are rather thin, there is a very distinct and long cardiac cavity. The cells of the intestine are of large size so that few are required to build a circumference. They are filled with scattered granules of pretty uniform size, which give rise to a coarse and rather obscure tessellation. The nature of the ventral gland remains unknown. The rectum is extremely short, being not more than half as long as the diameter of the body just in front of the anus. The longitudinal fields are visible throughout most of the length of the worm, and are about two-fifths as wide as the body. The nerve-ring as is usual in this genus, is well forward. It surrounds the oesophagus squarely, and is about as wide as the oesophagus at the point encircled. The tail is one of the most characteristic features. It has the general contour of a hand folded in the act of pointing with the forefinger, that is, the form of a printer's index or fist. The diameter of the body increases somewhat just in front of the anus and diminishes suddenly at the anus, so that the beginning of the tail is very considerably less in diameter than the portion of the body immediately in front of the anus. Caudal glands are present in the form of three egg-shaped glands located opposite the anus. The length of these glands is about equal to half that of the anal body-diameter. Their secretion is emptied through ducts which terminate at the tail end, which is slightly apiculate and apparently destitute of papillae. The tail, like all other portions of the body, appears to be completely naked. The body musculature ceases at the middle of the tail and the posterior half of this organ is therefore quite transparent. This portion is cylindrical and has a diameter about equal to one-fourth or one-fifth of that of the body at the anus. The vulva is somewhat salient although it is far from being a conspicuous feature. The sexual organ is single and extends forward, the vagina being very short, not over one-fourth as long as the adjacent body-

diameter. The eggs are of large size considering the size of the uterus. A single egg not yet passed on to the uterus was four-fifths to five-sixths as wide as the body and about three times as long as wide. At that stage it had a very thin covering. At a later stage the covering was no thicker. I am not certain whether these eggs do not pass through all the early stages of segmentation before being deposited. I can only suggest from the appearances that this is possible, but unlikely. The ovary is reflexed and reaches a little more than half way back to the vulva.

The male remains unknown.

Habitat. This species was common about the roots of diseased cane, Kipahulu Plantation, Maui, September, 1905. Also Niulii, Hawaii, September, 1905, about the roots of diseased cane.

Mononchus brachyuris Bütschlii. (2)

			30.		
2.	7.5	28.2	65.5	96.8	1.92 mm.
2.3	2.9	3.5	3.9	1.9	

The colorless, hairless skin is without markings of any sort. The cylindroid neck ends in a continuous sub-truncate head. There are no setae. The six lips are of the form characteristic of the genus and bear twelve papillae in two rows of six each. The lateral organs consist apparently of transverse slits opposite the middle of the pharynx. This species is eyeless like all others of the genus. The pharynx is one-half as wide as the head and is armed with a single dorsal tooth whose point is located a trifle in front of the middle. It is massive in structure and fills up the pharynx more than is usual in this genus. Rasp-like surfaces exist on the lateral walls of the pharynx opposite the region of this dorsal tooth. Anteriorly the cylindroid oesophagus is one-half as wide as the neck, while posteriorly it is three-fifths as wide. It has the usual thick conspicuous chitinous lining. The conspicuous cardiac column is so deeply constricted as to be only one-half the diameter of the base of the neck. The intestine becomes at once three-fourths as wide as the body. There is a small cardiac cavity in which the cardia can be plainly seen. The cells of the intestine are tessellated. The oblique rectum is equal in length to the anal body-diameter. The longitudinal fields were not clearly seen. The nerve-ring encircles the oesophagus squarely. The tail is conoid to the truncate terminus and contains three caudal glands located opposite to, or a little in front of, the anus. This latter is conspicuous, being somewhat raised. The vulva is a conspicuous feature owing to the thickness of the chitinous walls of the vagina, which is one-half as long as the body-diameter. The sexual organs are double and occupy a space two-thirds as long as the neck. The eggs are probably ellipsoidal, but not much elongated. The sexual organs are reflexed.

Habitat. About the roots of diseased cane, Hilo, island of Hawaii, August 20, 1905.

Mononchus brachyurus has been identified in the following locations on the islands of Oahu and Maui, 1926-1931.

Fields of Honolulu Plantation Company (around the roots of sugar cane); Kaimuki (garden soil); Moanalua Gardens (garden soil); fields of Waialua Agricultural Co., Ltd., (around roots of sugar cane and pineapples); fields of Hawaiian Commercial and Sugar Company, Ltd. (around the roots of sugar cane); slopes of Haleakala at an elevation of approximately 7000 feet (around the roots of *Taraxacum officinalc,* [dandelion] Weber.).

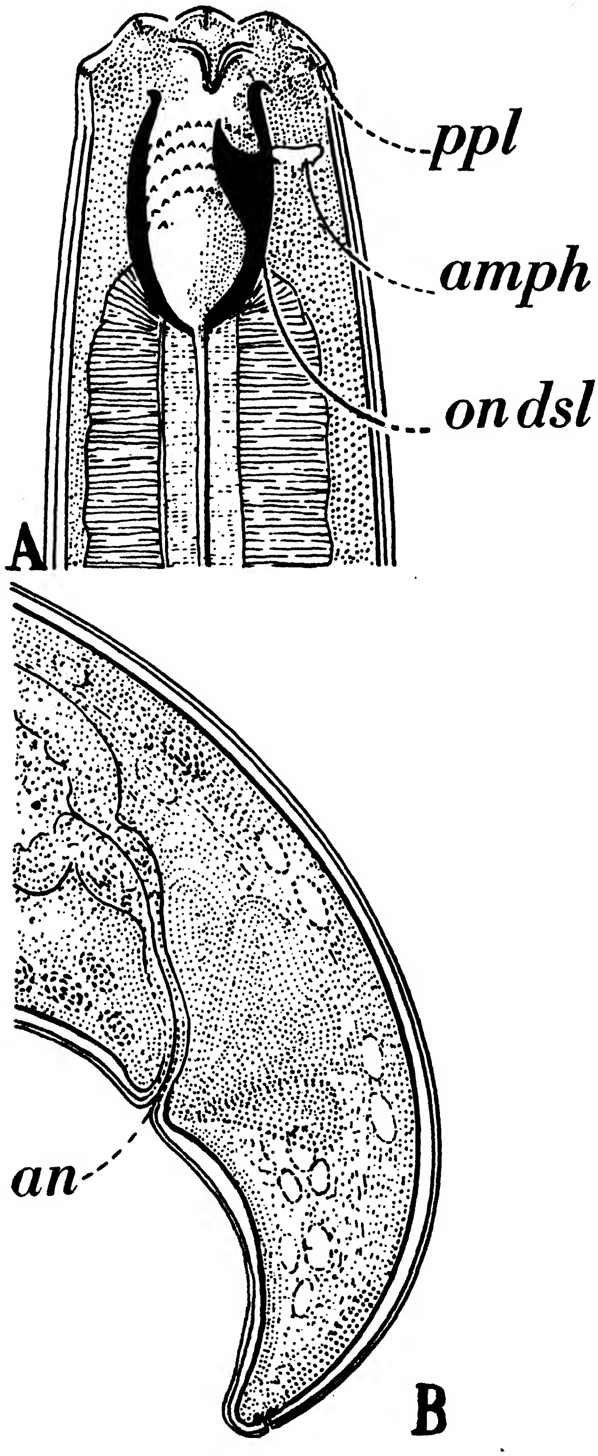

Fig. 16. **Mononchus brachyuris.**
A. Head end of adult female. *amph*—amphid; *on dsl*—dorsal tooth; *ppl*—papilla.
B. Tail end of adult female. *an*—anus. (× 1400).

Mononchus papillatus, Bastian. (3)

$$\frac{3.}{2.6}\quad\frac{9.3}{3.5}\quad\frac{26.}{3.8}\quad\frac{62.}{4.3}\quad\overset{27.}{-}\quad\frac{93.}{2.4}\quad 1.1\text{ mm.}$$

Glands are present in the segments of the oesophagus, and are most strongly developed in the posterior half. The secretion of the glands in the dorsal segment pours into the lumen of the oesophagus through a minute pore near the middle of the neck, a short distance behind the nerve ring. Under favorable conditions lenses of the highest power show transverse striae to be interrupted on the lateral lines, where there are two refractive longitudinal striations very close together. What appears to be an ordinary ventral renette pore is found a short distance behind the nerve-ring. The writer's investigations prove this species to be syngonic. The longitudinal ribs of the pharynx, probably three in number, are a little more prominently developed than usual. Occasionally a subventral or submedian rib of the pharynx shows traces of most exceedingly fine denticles. Only the most careful examination of favorable specimens shows these denticles. The writer has never observed a denticulated ventral rib like that of *muscorum* as mentioned by Menzel.

A common, voracious, cosmopolitan, nemativorous species. Found in many parts of Europe and of the United States, and also in Hawaii, Australia, South America and Asia.

Specimens of this species have been identified (1926-1931) in soils of cane and pineapple fields, Oahu and Maui.

LITERATURE CITED

(1) Steiner, G., and Heinly, H. 1922. The possibility of control of *Heterodera radicicola* and other plant-injurious nemas by means of predatory nemas, especially by *Mononchus papillatus* Bastian. Journ. Wash. Acad. Sci. XII, pp. 377-379, 382-383.

(2) Cobb, N. A. 1906. Fungus maladies of the sugar cane. Bull No. 5, Div. of Path. & Physiol., H. S. P. A. Expt. Sta., pp. 179-182.

(3) Cobb, N. A. 1917. The Mononchs. Soil Science, III, p. 458.

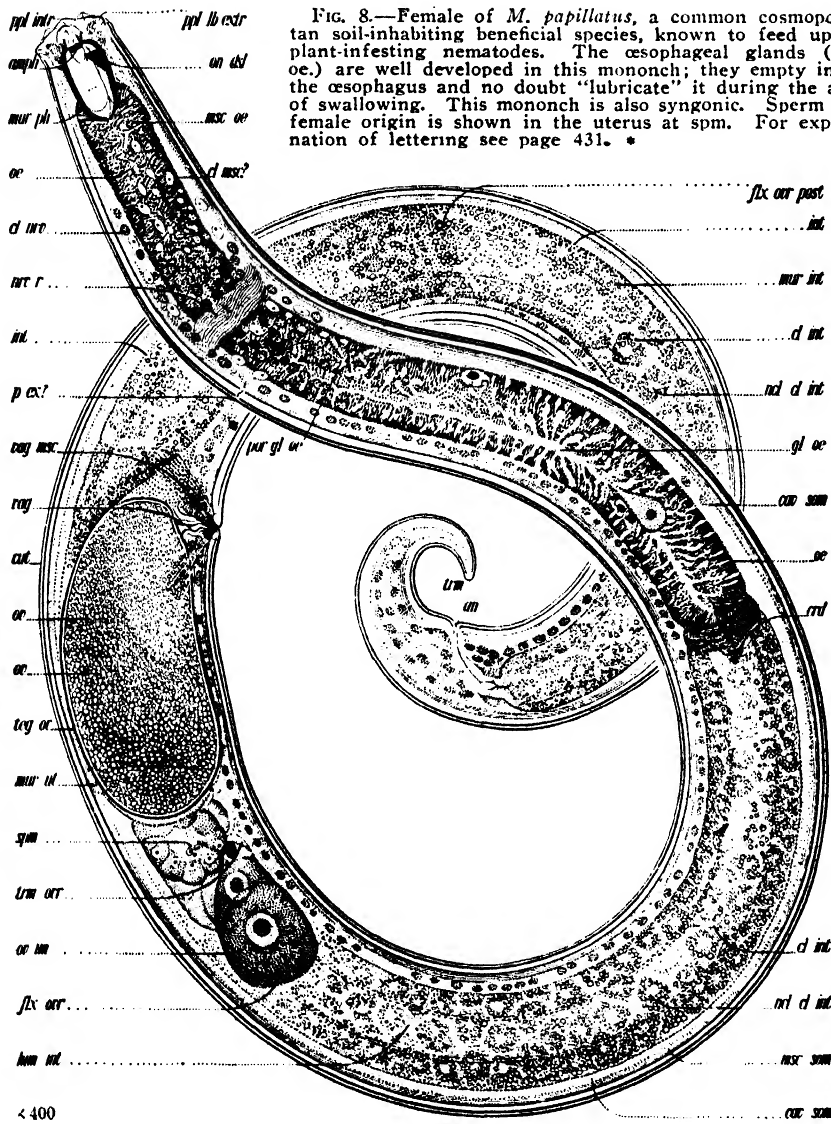

FIG. 8.—Female of *M. papillatus*, a common cosmopolitan soil-inhabiting beneficial species, known to feed upon plant-infesting nematodes. The œsophageal glands (gl. oe.) are well developed in this mononch; they empty into the œsophagus and no doubt "lubricate" it during the act of swallowing. This mononch is also syngonic. Sperm of female origin is shown in the uterus at spm. For explanation of lettering see page 431. *

Fig. 17.

After Cobb.

* Soil Science, 1917, Vol. III, p. 441.

Steer "Dry Lot" Fattening Experiment

By V. Eremeef and C. G. Lennox

Location: Conducted at Waianae Company from June 15, 1928, to September 1, 1928. The feeding was under the supervision of V. Eremeef, of Waianae Company.

Object: To finish off feeder steers in a dry lot using a mixture of molasses, bagasse and protein supplement as a complete feed ration. The ration used was substantially the same as that employed by the Honokaa Sugar Company in feeding plantation work animals. A description of the feeding at Honokaa was published by W. P. Naquin in the *Hawaiian Planters' Record*, October, 1929.

Equipment: Twelve steers were penned in a corral approximately 200′x200′ in size. Abundance of shade and wind protection was afforded by trees growing in the corral. A good supply of water was present at all times. A cattle chute was built on one side of the corral with a large platform scales placed in the center. The steers were run through the chute singly and held on the scales until correctly weighed and then released.

Progress Notes: June 14, 1928. Twelve steers were selected from a herd which had been grazing on the Waianae kiawe range land. The animals ranged from small yearlings to big three-year olds. They were not in good flesh and were quite wild.

Nine of the animals were half Polled Angus and half nondescript. Two showed evidence of Short Horn blood, and one was nondescript. The entire 12 were driven into the above-mentioned corral.

June 15, 1928. Weighed 11 steers. One escaped over the corral fence and was never returned.

June 15-22, 1928. The feeding of the bagasse mixture was made gradual by feeding a quantity of cane tops with it during the first week. The lighter mixture of Formula I (see Table) was fed during the first week.

Starting the second week the steers were given nothing but the mixture of Formula II (see Table). They were given no other feed except this.

August 21, 1928. Steers weighed a second time. Only 10 were weighed as one had escaped. Formula changed at this date to Formula III which was more concentrated.

September 11, 1928. Steers weighed a third time. One was too elusive so only 9 were weighed. Experiment discontinued.

Discussion: During the progress of the experiment the steers were disturbed as little as possible. They were in a clean, dry paddock well shaded and always supplied with fresh water and rock salt. The bagasse mixture was placed in feeding troughs in the early morning and late afternoon. The amount put in was governed by the amount left by the previous feeding, it being desirable to have only a very small quantity left over.

In round figures each steer ate about 25 pounds of the mixture daily, or 50 quarts.

The cost figures on such an experiment would likely be quite misleading since so much of the work had to be done by trial and error until a satisfactory technique was established. The cost of mixing the feed could be greatly reduced if a factory was equipped to do such work. In this case a small concrete mixer was used which was slow and costly.

A table is presented showing the approximate cost per pound gain of steers. This figure represents only the feeding ingredients used.

No estimate has been made of cost of mixing, overhead, interest on investment, loss of animals by death and other charges which would raise the total cost per pound gain by a considerable margin.

Summary: Ten steers were fed in a dry lot on a "finishing off" ration of molasses, bagasse and soy bean meal. During the period of the experiment (89 days) the daily gain per steer was approximately 3 pounds per day. At the start of the experiment the steers were thin and shaggy, at the end they were well rounded and shiny. The daily gain in the first period was slightly greater in the first 67 days than in the second 22 days of the experiment, even though the mixture in the second period was more concentrated. The economic length of a "finishing off" period could be best determined by further experimentation.

The results of this experiment are presented as a lead to a profitable use of molasses. Further experiments along this same line should be conducted before adoption as a commercial proposition.

Formulas used—No. of pounds of each ingredient per concrete mixer full.

Ingredients	Formula I	II	III
Bagasse	24	24	24
Molasses	32	48	52.5
Soy bean meal	7	9.6	9.6
	63	81.6	86.1

Analysis of materials.

Materials	Dry Matter	Per 100 Pounds of Material: Digestible Crude Protein	Total Digestible Nutrients
Molasses	74.3	1 to 2	39.5 to 53
Soy bean meal..............	90	38.6	82.6
Bagasse analysis approx.......	75	.4	46.3

Analysis of Formulas I and III in terms of 100 lbs. of mixture.

Formula I	D. M.	D. C. P.	T. D. N.	Nutritive Ratio	Weight per Quart
50.8 pounds molasses......	37.8	.76	28		
11.1 pounds soy bean meal	10	4.3	9.2		
38.1 pounds bagasse	28.6	.15	17.6		
100	76.4	5.21	54.8	10.5	½ pound
Formula III					
61 pounds molasses......	45.4	.91	33.6		
11.1 pounds soy bean meal	10	4.3	9.2		
27.9 pounds bagasse	21	.11	12.9		
100	76.4	5.32	55.7	10.5	

Table of Feed Consumption and Costs.

Period 1—June 15 to August 21, 1928.

Formula II used at the rate of approximately 250 pounds of mixture per day.

Approximately 8¼ tons of Formula II consumed.

Bagasse	2.43 tons	at	$ 2.98 per ton=	$ 7.25
Molasses	4.85 tons	at	5.00 per ton=	24.23
Soy bean meal.............	.97 ton	at	62.00 per ton=	60.01
	8.25 tons			$91.49

No. of pounds gained by steers............................2072

No. of pounds feed consumed per pound gain in weight......7.96

Feed cost per pound gain in weight......................$.044

Period 2—August 21 to September 11, 1928.

Formula III used at rate of approximately 250 pounds of mixture per day.

Approximately 2½ tons of Formula III consumed.

Bagasse	.697 ton	at	$ 2.98 per ton=	$ 2.08
Molasses	1.521 tons	at	5.00 per ton=	7.60
Soy bean meal...........	.279 ton	at	62.00 per ton=	17.30
	2.50			$26.98

No. of pounds gained by steers............................ 582

No. of pounds feed consumed per pound gain in weight......8.6

Feed cost per pound gain in weight....................$.0464

Record of Steer Weighings.

	Description of Steer	June 15/28	Aug. 21/28	Sept. 11/28
1.	Black—white spot on left hind leg..........	460	749	770
2.	Pure black—biggest—longer head...........	745	872	927
3.	Black—white face	765	792	825
4.	Pure black—smallest	230	480	547
5.	Brown—broken triangle on forehead........	500	795	878
6.	Brown—perfect triangle on forehead........	455	687	768
7.	White	455	649	732
8.	Black—white spot on belly	295	461	574
9.	Black—shaggy brown tinge—sign of horns..	410	687	...
10.	Black—small—spotted white face...........	261	487	533
	Total............................	4587	6659*	6554

Computation of daily gain in weight.

	Period No.	Total Gain in Weight	No. Steers	Gain per Steer	No. Days	Pounds Gain per Day per Steer
1.	June 15-Aug. 21	2072 pounds	10	207.2 pounds	67	3.09
2.	Aug. 21-Sept. 11	582 "	9	64.7 "	22	2.94

* In computing for period No. 2, Steer No. 9 is omitted and the total used is 5972 instead of 6659.

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
MARCH 16 TO JUNE 9, 1931

Date	Per Pound	Per Ton	Remarks
Mar. 16, 1931	3.20¢	$64.00	Philippines, Cubas.
" 17	3.25	65.00	Cubas, Philippines, Porto Ricos.
" 18	3.245	64.90	Philippines, 3.23, 3.26.
" 19	3.31	66.20	Philippines, 3.30; Porto Ricos, 3.30, 3.32.
" 24	3.345	66.90	Philippines 3.34, 3.35; Porto Ricos, 3.35; Cubas, 3.35.
" 26	3.35	67.00	Porto Ricos, Philippines.
" 30	3.33	66.60	Cubas.
Apr. 8	3.35	67.00	Porto Ricos.
" 13	3.33	66.60	Philippines.
" 15	3.31	66.20	Porto Ricos, 3.32, 3.30.
" 16	3.28	65.60	Porto Ricos.
" 17	3.27	65.40	Philippines.
" 20	3.275	65.50	Cubas, 3.30; Philippines, 3.25.
" 21	3.25	65.00	Philippines, Porto Ricos.
" 23	3.27	65.40	Porto Ricos.
" 25	3.25	65.00	Philippines.
" 28	3.20	64.00	Porto Ricos.
" 30	3.22	64.40	Porto Ricos.
May 1	3.235	64.70	Philippines.
" 4	3.21	64.20	Philippines, 3.22, 3.20.
" 5	3.20	64.00	Porto Ricos.
" 6	3.145	62.90	Philippines, 3.15; Porto Ricos, 3.15, 3.14.
" 8	3.16	63.20	Philippines, 3.14; Cubas, 3.18.
" 11	3.18	63.60	Porto Ricos.
" 15	3.20	64.00	Porto Ricos.
" 16	3.23	64.60	Philippines.
" 18	3.24	64.80	Porto Ricos, 3.23; Philippines, 3.25.
" 20	3.20	64.00	Philippines.
" 21	3.16	63.20	Philippines.
" 22	3.15	63.00	Porto Ricos.
" 26	3.125	62.50	Porto Ricos, 3.11, 3.14; Philippines, 3.13, 3.12.
" 28	3.16	63.20	Philippines, 3.15, 3.17.
" 29	3.215	64.30	Philippines, 3.20; Porto Ricos, 3.20, 3.23.
June 1	3.24	64.80	Porto Ricos, 3.23, 3.25; Philippines, 3.23, 3.25.
" 2	3.235	64.70	Porto Ricos, 3.24; Philippines, 3.24, 3.23.
" 4	3.20	64.00	Philippines.
" 5	3.25	65.00	Porto Ricos.
" 9	3.30	66.00	Cubas, Philippines, Porto Ricos.

THE HAWAIIAN PLANTERS' RECORD

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A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Pre-Harvest Samples:

A timely article on pre-harvest sampling is submitted by William Wolters, of the Oahu Sugar Company, Ltd. He describes in detail the method developed and used by the Oahu Sugar Company. Results for the last three years, showing a very close correlation between the pre-harvest and actual figures, are also given. This article is well worth very careful study.

A Report on the Local Use of Student's Method:

Several of the methods which have been used in Hawaii for arriving at the significance of results from field experiments are discussed by O. H. Lyman. The advantages of Student's Method are pointed out, and examples are given illustrating its use.

Kutsunai's modification of Chauvenet's criterion is considered a satisfactory basis for discarding plots which fluctuate too widely from the means of their series.

Root Pressure and Root Pressure Liquids of the Sugar Cane Plant:

A technique of collecting root pressure liquids from stools of cane growing under field conditions in quantities sufficiently large for chemical analyses is reported. The composition of these liquids is suggested as an approach to the nutritional problems of the cane plant.

The root pressure, as measured by columns of mercury, the heights of which rose at night and fell during the day, was correlated with the percentage of moisture in the soil. The root pressures exhibited by different varieties of cane were correlated with their relative drought resistance, which suggest a method

of determining in advance of field trials the relative drought resistances of new cane varieties.

When tubes filled with a solution were attached to but one cut stalk of a stool, this liquid was drawn into the plant body through the cut stalk. This technique is suggested as a means of studying direct effects of various forms and amounts of liquids and gases, salts, enzymes, vitamines, disinfectants, stimulants, etc., when thus introduced "hypodermically" into stools of growing cane.

Temperature, Rainfall and Sunshine Data on Hawaiian Sugar Plantations:

This article is a compilation of miscellaneous weather data of the plantations in this Territory. It is hoped that the data herein presented will stimulate and facilitate the study of the relation of weather conditions to sugar yields, and thereby enable us to make a more accurate measure of the effect of other influences on yields.

A Rapid Method for the Determination of Potash:

Rapid methods for determinations of plant nutrients in soil extracts, soil percolates and irrigation waters are much needed for agricultural research and control. A colorimetric method for the determination of potash has been adapted to this type of analysis, which is more than four times as rapid as the standard gravimetric method, and which possesses a somewhat greater accuracy than the older method when applied to this class of materials.

Manganese as an Essential Element in the Growth of Sugar Cane:

A brief description of experimental work done elsewhere on the relation of manganese to plant growth is presented, with a discussion of the problems which arise in connection with such experiments. An investigation pursued at this Experiment Station is then described.

It is concluded that manganese is essential to the normal growth of sugar cane. In the complete absence of manganese, symptoms appear which are characteristic of the physiological disease known as Pahala blight.

Root Pressure and Root Pressure Liquids of the Sugar Cane Plant

By D. M. Weller

Contents

I. Introduction

Some recent experiments with cane plants growing both in sand cultures and in the field have proven so suggestive and, when reported in the *Monthly Letter* of the Experiment Station, have aroused such general interest that, although in an early stage of their development, the following paper, offered as a progress report, seems to be justified.

The first of these experiments was reported under date of February 25, 1930, as follows:

> A young cane plant of the variety P. O. J. 36 growing in sand culture was cut off just above the surface of the sand. By means of rubber tubing, a glass tube of one-inch diameter was attached in an upright position to the stump. A small amount of distilled water was poured into the glass tube to prevent the cut-off end of the stalk from drying. Soon a column of liquid began to rise in the glass tube and after a number of days attained a height of about 15 cm. After 15 days, this column was still rising slowly.

Similar results were obtained when this experiment was repeated with cane of other varieties (H 109, Lahaina, Yellow Caledonia, and D 1135) also growing in sand cultures. This group of experiments is referred to as Series A.

II. Purpose and Plan

As was mentioned above, the plants of Series A were growing in sand cultures and, when the columns of liquids as the result of root pressure were seen rising in the attached tubes, one could not help wondering how their chemical composition differed from the culture solutions with which the plants were irrigated.

The general purpose of this work became, therefore, (1) to determine whether or not the composition of root pressure liquids obtained from cane plants growing in sand cultures differed from that of the culture solutions with which the plants were irrigated and, if so, in what respect; (2) to determine whether or not the composition of root pressure liquids obtained from plants growing in the field differed from the composition of a true soil solution, or from that of a 1 per cent citric acid extract of the soil in which the plants were growing and, if so, in what respect; and (3) whether or not such comparisons would result in a method for determining the requirements of plant nutrients (soil deficiencies, availabilities, etc.) and water of cane at given ages grown under different field conditions.

III. General Development

Following those of Series A the next experiments were confined to plants growing in the field. Glass tubes of one-inch diameter were attached to the stumps of these plants in the same manner as they were attached to those growing in the sand cultures. Plants of the varieties H 109, Yellow Caledonia, D 1135 and P. O. J. 36 were used. This group of experiments was continued over a period of ten days and is referred to as Series B.

Sterile, distilled water was added to each tube until the level of the added water stood at a convenient height above the rubber connection of each tube. This level was established on each glass tube as the zero point. The attachments were made during the period from 9:00 a. m. to 12:00 m. on Saturday. By 12:00 m. of the same day, the column of liquid in the tube attached to the H 109 plant (the first attachment to be made in this series) had risen 18.5 cm. above the zero point. This level was lowered to the zero point by removing 10.5 ml. of the liquid. At 9:00 a. m. on the following Monday, instead of rising above, the liquid had descended below the zero point and water was added to the tube to re-establish the level of the liquid at the zero point again. On each succeeding day of the remainder of the 10-day period it was necessary to re-establish the level of the liquid at the zero point by adding water to the tube.

By 9:00 a. m. on the following Monday~~, and~~ each succeeding day up to the fifth day, following the attachment of the tube to the Lahaina plant, the level of the liquid in the tube had sunk below the zero point but was re-established by adding water to the tube. On the fifth day, there was a rise of 2.0 cm. of the column

in the tube, which height remained constant throughout the remainder of the 10-day period.

At 9:00 a. m. on Tuesday following the attachment, the height of the liquid in the tube attached to the Yellow Caledonia plant stood at 43.0 cm. above the zero point and was lowered to the zero point by removing 35.5 ml. of the liquid. On each succeeding day of the 10-day period, the level of the liquid was below the zero point but was brought up to the zero point each day by the addition of water.

In the case of both the D 1135 and the Uba plants, no head of liquid above the zero points was obtained but on each day of the 10-day period the level of the water in each tube was found to be below the zero point. Water was added each day to re-establish the level of the water in the tubes at the zero points.

Before describing the behavior of the P. O. J. 36 plant, attention should be directed to the fact that the plants of Series A were constituted of but one stalk. Those of Series B were constituted of from three or four to a dozen stalks and of this number but a single stalk was cut. Because of the underground connections with this stalk, the stalks of the stool left uncut could by "leaf pull" draw away from the cut stalk the liquid which might otherwise collect in its attached tube.

No head of liquid resulted in the case of the P. O. J. 36 attachment but water had to be added each day to the tube because the level of the liquid had always sunk below the zero point. On April 12 instead of an empty glass tube a burette was attached and filled with water to the 50 ml. mark. On April 25, 43.0 ml. had been sucked from the burette into the plant and, on April 26, 50 ml. had been drawn into the stool. From these data, i.e., the fact that liquids may thus be drawn into the plant body, the idea of using this technique as a means of studying the effects of various forms and amounts of liquids and gases when thus introduced directly into stools of growing cane naturally suggested itself. This will be referred to later under the heading of "Suction Feeding."

A. Development of Technique of Collecting Root Pressure Liquids for Chemical Analyses.

Several series of experiments now followed, the object of which was to secure for chemical analyses larger quantities of liquids within a shorter period of time so that the general purpose of this work as stated above could be carried out. Two plants of Yellow Caledonia were selected for the first of these series and are referred to as D-1 and D-2. Instead of permitting a head of liquid to result in attached one-inch tubes as in the preceding experiments, one-fourth inch tubing was connected in such a way as to lead the root pressure liquids off at right angles to the stumps into attached flasks. (See Fig. 1.)

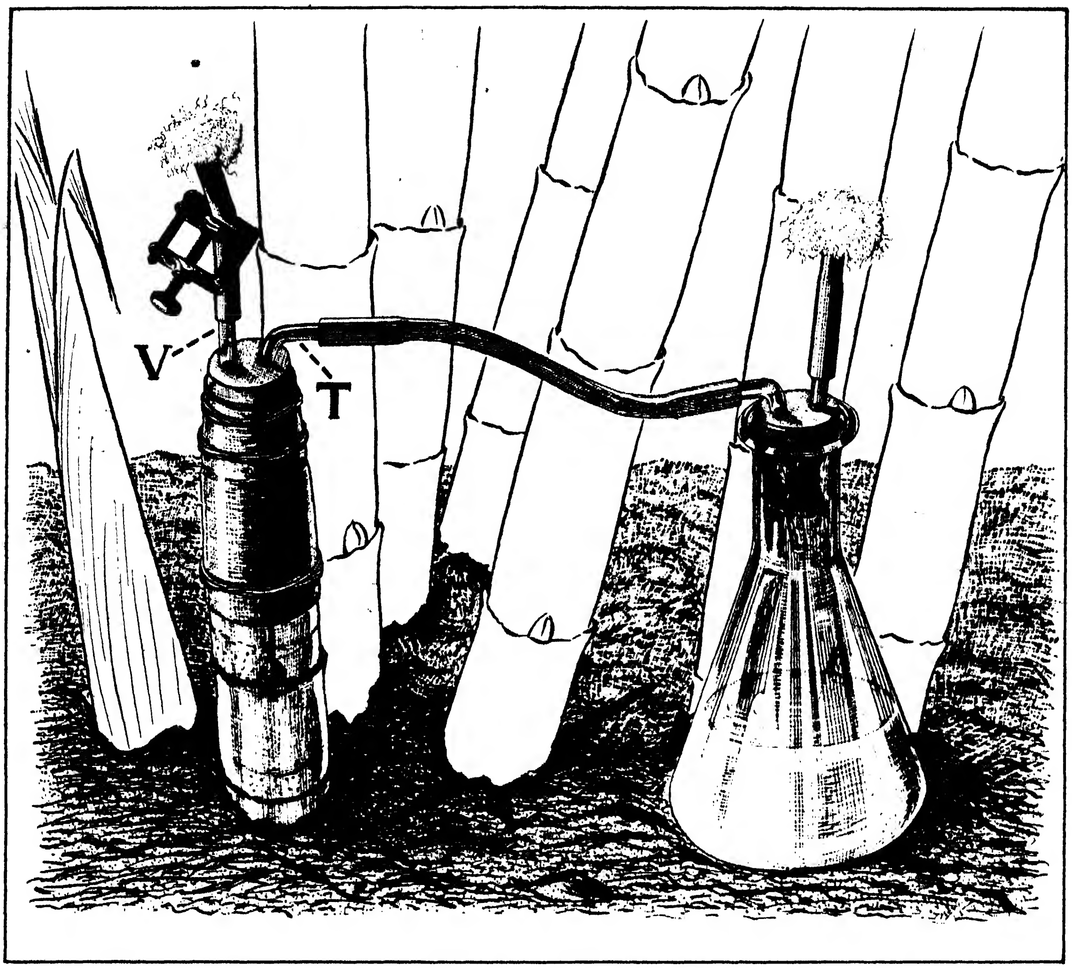

Fig. 1. Showing in detail the method of attaching flasks to the stumps of cane stalks for the purpose of collecting root pressure liquids for chemical analyses. V, vent; T, glass tubing leading to flask.

The flask was thus attached to a secondary stalk of D-1. (Fig. 2, A.) Water was added through the vent (Fig. 1, V) to prevent the cut end from drying. It was observed that this added water, which filled the vent tube and part of the tube leading to the flask, was almost immediately drawn into the plant and, although water was added repeatedly, it was just as often drawn into the plant. While this process was being observed, the idea occurred that the added water could be prevented from being drawn into the plant by decapitating the adjoining primary stalk. The top of the primary stalk was, therefore, struck off at about the 75 cm. level. Almost immediately root pressure liquid began to rise in the vent tube and in the tube leading to the flask and, when the vent tube was closed with the screw compressor clamp, liquid began to follow slowly along the tube leading to the flask (Fig. 1, T). The amount of liquid thus collected in the flask is shown in Table I.

TABLE I

SHOWING THE AMOUNTS OF ROOT PRESSURE LIQUID COLLECTED FROM A DECAPITATED SECONDARY SHOOT OF A YELLOW CALEDONIA PLANT AT THE INTERVALS INDICATED

Date	Time	ml. Removed	
1930			
April 8....................	1:00 p. m.		(Attachment made)
" 12....................	8:00 a. m.	310.0	
" 13....................	8:00 a. m.	280.0	
" 15....................	8:00 a. m.	225.0	
" 23....................	8:00 a. m.	270.0	
Total.................		1,085.0	

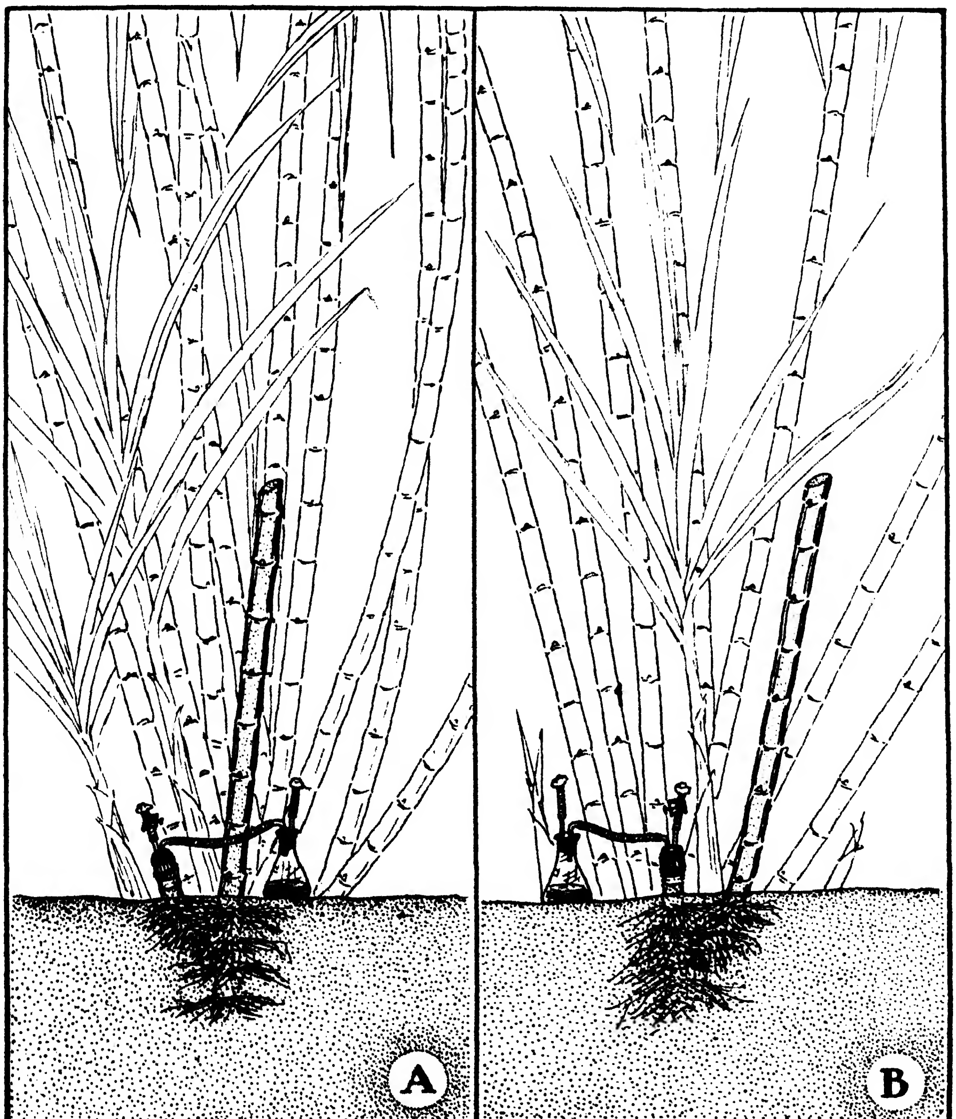

Fig. 2. Showing attachment of flask to a secondary stalk (A), and to a primary stalk (B) of a cane plant. The stalks to which the flasks are attached are cut off at the 15 cm. level while an adjoining stalk of each is cut off at the 75 cm. level.

In the same way attachment was next made to the *primary* stalk of the plant of D-2 (Fig. 2, B) but, even though water was repeatedly added to the tube through the vent, no root pressure liquid rose in the vent tube or the tube leading to the collection flask.

The experiments of Series D were repeated. Attachments were made to primary stalks cut high (75 cm. above the ground level), primary stalks cut low (15 cm. above the ground level), and to secondary stalks also cut high and cut low. These experiments are referred to as Series E-1 to 5, the attachments of which are shown diagramatically in Fig. 3. The amounts of root pressure liquids collected are shown in Table II.

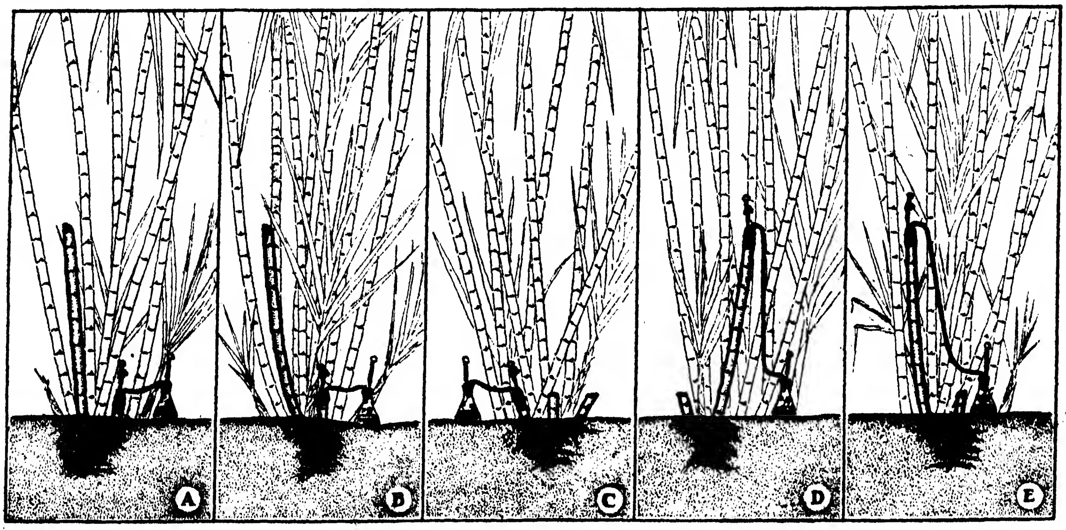

Fig 3. Showing the attachments of Series E-1 (A), E-2 (B), E-3 (C), E-4 (D), and E-5 (E). (Explanation in the text.)

TABLE II

SHOWING THE AMOUNTS OF ROOT PRESSURE LIQUIDS COLLECTED FROM PRIMARY AND SECONDARY STALKS OF YELLOW CALEDONIA CANE WHEN CUT HIGH (75 CM. ABOVE THE GROUND LEVEL) AND CUT LOW (15 CM. ABOVE THE GROUND LEVEL)

Series	Date 1930	Attachment Made To	Height of Stump	Duration	Total Amt. of Root Pressure Liquid	Average ml. per Day
E–1	April 19–May 15	Secondary	15 cm.	26 days	1,308	50.3
E–2	" 23– " 15	Primary	15 cm.	22 days	645	29.3
E–4	" 24– " 15	Primary	75 cm.	21 days	366	17.4
E–5	" 24– " 15	Secondary	75 cm.	21 days	199	9.4
E–3	" 24– " 15	Secondary	15 cm.	21 days	0	0.0

The indications of the data of Table II are that greater amounts of liquid may be obtained when attachments are made to stalks cut low than when made to stalks cut high and that greater amounts may be obtained from secondary stalks than

from primary stalks. These indications will not be discussed here but, in light of additional data, an explanation will be suggested under the discussion. The behavior of E-3, which was not only a secondary stalk, but was also cut low, was the exception rather than the rule, an explanation of which will be offered under the discussion.

In the next series of experiments (F-1 to 10) D 1135 cane was used. Attachments were made to primary and secondary stalks separately and to primary and

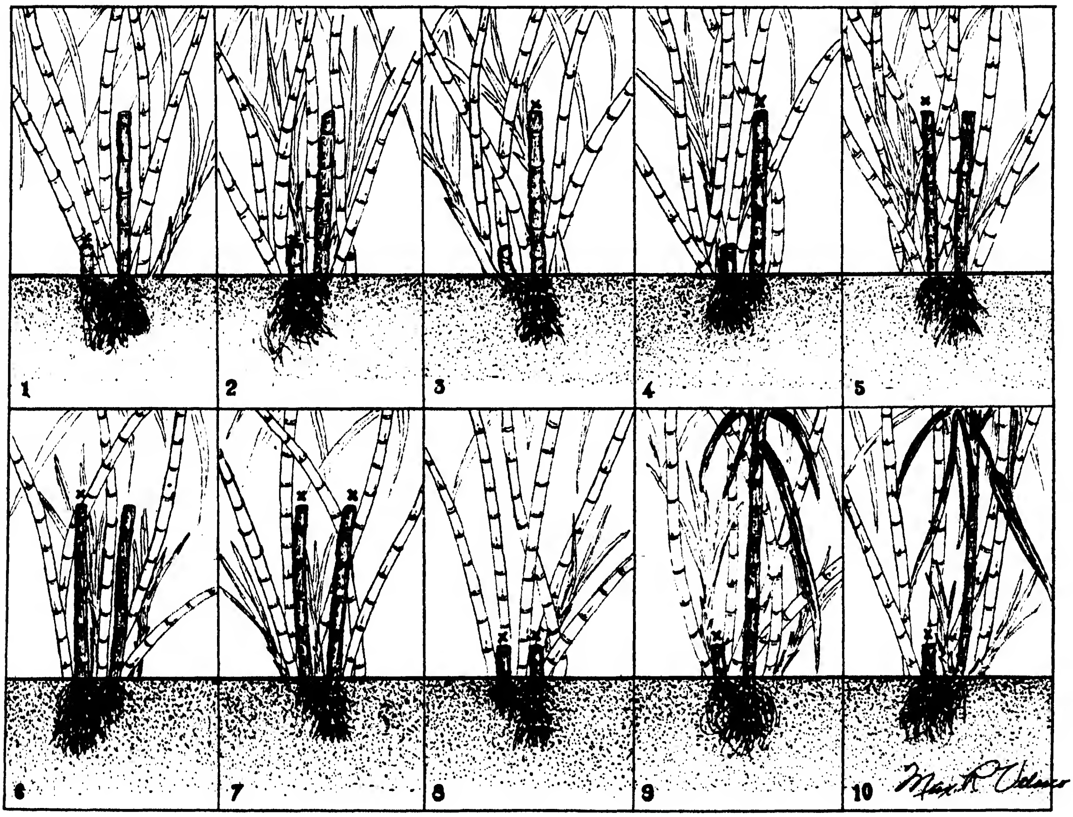

Fig. 4. Showing diagramatically the attachments of Series F-1 to 10. Points of attachment indicated by the letter X. (Explanation in the text.)

secondary stalks simultaneously. When such attachments were made separately, the adjoining primary or secondary stalk was decapitated either "high" or "low." When attachments were made to two stalks of a stool simultaneously, the liquid was conducted by means of a glass Y-tube and rubber hose connections to a common flask. These various combinations are shown diagramatically in Fig. 4. All attachments were made on May 7 and the amounts of liquids collected determined on May 12, 1930. These data are shown in Table III.

TABLE III

SHOWING AMOUNTS OF ROOT PRESSURE LIQUIDS COLLECTED FROM D 1135 CANE OVER A 5-DAY PERIOD. ATTACHMENTS WERE MADE TO PRIMARY AND SECONDARY STALKS CUT HIGH (75 CM.) AND CUT LOW (15 CM.) SINGLY AND IN COMBINATION. THE ADJOINING STALKS WERE ALSO CUT HIGH OR CUT LOW. (See Fig. 4.)

Series	No. of Attach-ments	Attachments Made To	Height of Attached Stump	Height of Adjoining Unattached Stump	Total Amt. of Root Pressure Liquid	Average mls. per Stalk
F-8	2	Primary &	15 cm.	..	161.0 ml.	80.5
		Secondary	15 cm.	..		
F-5	1	Secondary	75 cm.	75	64.0 "	64.0
F-1	1	Secondary	15 cm.	75	61.0 "	61.0
F-7	2	Primary &	75 cm.	..	109.0 "	54.5
		Secondary	75 cm.	..		
F-6	1	Primary	75 cm.	75	43.0 "	43.0
F-2	1	Primary	15 cm.	75	24.0 "	24.0
F-10	1	Primary	15 cm.	(Uncut)	8.5 "	8.5
F-3	1	Primary	75 cm.	15	4.0 "	4.0
F-9	1	Secondary	15 cm.	(Uncut)	3.0 "	3.0
F-4	1	Secondary	75 cm.	15	1.0 "	1.0

The indications of the data of Table III agree with those of Table II in that more liquid may be obtained from stalks cut low rather than high. There is a further indication that when attachments are made to more than one stalk, the average amount of liquid per stalk exceeds that of either primary or secondary stalks attached singly.

Five stools of H 109 cane were next selected. These are referred to as Series G-1 to 5. Stalks were not cut off and left unattached as in the previous series but attachments were made to all of the stalks which were cut off, as shown diagramatically in Fig. 5.

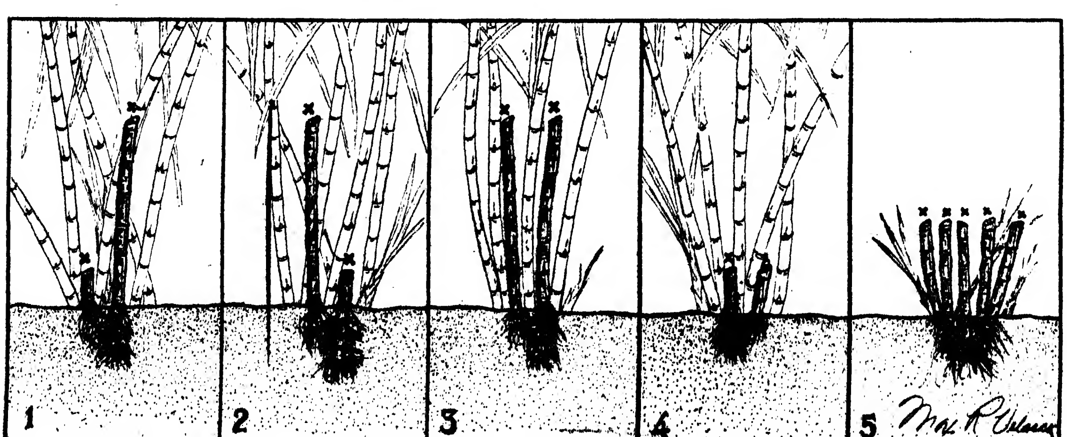

Fig. 5. Showing diagramatically the attachments of Series G-1 to 5. X indicates points of attachment. (Explanation in the text.)

All attachments were made on May 14 and removed 5 days later. The amounts of root pressure liquids obtained are tabulated in Table IV.

TABLE IV

SHOWING THE AMOUNTS OF ROOT PRESSURE LIQUID OBTAINED FROM H 109 PLANTS IN A PERIOD OF 5 DAYS

Series	Attachments	Attachments Made To	Height of Stump	Total Amt. of Root Pressure Liquid	Average ml. per Stalk
G–5	5	1 Primary	15 cm.	825.0 ml.	165.00
		4 Secondaries	15 "		
G–2	2	1 Primary	15 cm.	122.0 ml.	61.00
		1 Secondary	75 "		
G–1	2	1 Primary	75 cm.	29.5 ml.	14.75
		1 Secondary	15 "		
G–4	2	1 Primary	15 cm.	7.5 ml.	3.75
		1 Secondary	15 "		
G–3	2	1 Primary	75 cm.	5.5 ml.	2.75
		1 Secondary	75 "		

It will be noticed that G-5 of this series, the first instance where attachments were made to all of the stalks of a stool, averaged 165 ml. per stalk for the 5-day period. This amount greatly exceeded the average amount per stalk when attachments were made to only two stalks per stool. This method of attachment is pictured in Fig. 6.

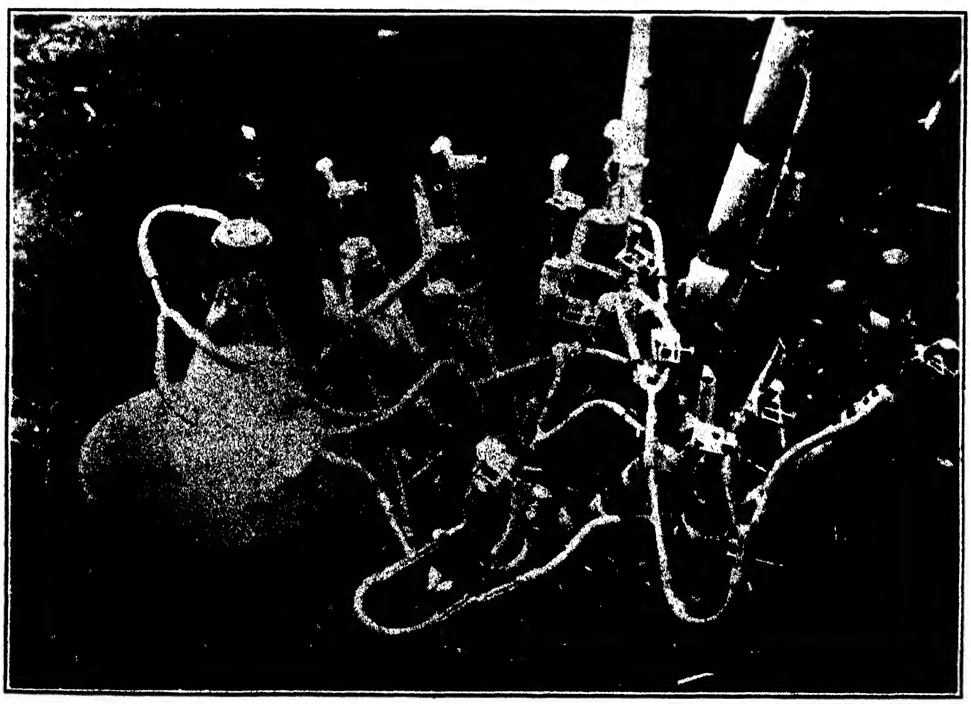

Fig. 6. Method of collecting root pressure liquids from the cane plant for chemical analyses.

The cane used for the experiments of Series B to G was plant cane almost two years old, somewhat neglected, and which was making little growth. The cane used in the next several series of experiments was vigorously growing, 9-months-old cane of the varieties H 109 and P. O. J. 2878. Half of the plantings of each of these two varieties had received applications of fertilizers while the other half had not.

B. Night vs. Day Collections

Two stools of H 109 cane of four stalks each were selected for the experiment of Series I. Each of these two stools was in the fertilized half of the H 109 planting and was composed of two primary and two secondary stalks. Because the technique used in G-5, where for the first time attachments were made to all of the stalks of a stool, had resulted in the collection of the greatest amount of liquid per stalk in a given period of time, the same method was used in this experiment. The stalks of one of these stools (I-1) were cut low (15 cm.) and those of the other (I-2) were cut high (75 cm.). The attachments were made during the afternoon of May 23, 1930. Beginning at 6:00 p. m. on the same day, the amounts of root pressure liquid obtained from each stool during successive 12-hour periods were measured and recorded. By measuring the amounts of liquid obtained at 6:00 a. m. and at 6:00 p. m. the relative amounts of liquids obtained during the day intervals could be compared with those obtained during the night intervals. These data are shown in Table V.

TABLE V

SHOWING THE AMOUNTS OF ROOT PRESSURE LIQUIDS OBTAINED FROM STOOLS OF FERTILIZED H 109 CANE WHEN ALL STALKS OF THE STOOLS WERE CUT "LOW" (I-1) AND CUT "HIGH" (I-2) AT THE INDICATED INTERVALS

1930	Time	Ml. Liquid Removed I-1	I-2
May 23	6:00 p. m.	61.0	16.0
" 24	6:00 a. m.	255.0	151.0
	6:00 p. m.	137.0	96.0
" 25	6:00 a. m.	151.0	108.5
	6:00 p. m.	91.0	84.0
" 26	6:00 a. m.	102.5	107.0
	6:00 p. m.	80.0	74.5
" 27	6:00 a. m.	86.5	79.5
	6:00 p. m.	65.0	59.0
" 28	6:00 a. m.	65.0*	77.0
	6:00 p. m.	57.0	55.0
" 29	6:00 a. m.	81.0	61.5
	6:00 p. m.	56.0	44.0
May 31	6:00 p. m.	238.0	186.0
June 1	6:00 p. m.	118.0	92.0
" 2	6:00 p. m.	110.0	79.0
" 3	6:00 p. m.	100.0	80.0
" 4	6:00 p. m.	108.0	71.0
Total		1,962.0	1,521.0

* At the time of this reading a leak had developed in one of the rubber tube connections of I-1.

Here, again, the data of Table V agree with those of Tables II, III and IV in indicating that more liquid may be obtained from stumps cut low than from those cut high, for a total of 1,962.0 ml. of liquid was obtained from I-1 as compared with a total of 1,521.0 ml. from I-2. The data of Table V show also that the amount of liquid collected during the first 5-day period exceeded even that of G-5 (165 ml.) by averaging 287.7 ml. and 222.8 ml. per stalk for I-1 and I-2 respectively.

Another indication of the data of Table V is that a greater quantity of liquid is pumped up by the cane plant at night than during the day. During the first 6 days 741.0 ml. of liquid were obtained from I-1 at night as compared with 486.0 ml. obtained during the day. From the plant cut high (I-2) 584.0 ml. were obtained at night as against 412.5 ml. obtained during the day. This is shown more clearly if, when the data of Table V are arranged as in Table VI, individual as well as total night readings are compared with their companion day readings.

TABLE VI

SHOWING THE AMOUNTS OF ROOT PRESSURE LIQUIDS OBTAINED AT NIGHT AS COMPARED WITH THE AMOUNTS OBTAINED DURING THE DAY FROM H 109 CANE CUT LOW (I-1) AND CUT HIGH (I-2)

1930	I-1		I-2	
	Night	Day	Night	Day
May 24	255.0 ml.	137.0 ml.	151.0 ml.	96.0 ml.
" 25	151.0 "	91.0 "	108.0 "	84.0 "
" 26	102.5 "	80.0 "	107.0 "	74.5 "
" 27	86.5 "	65.0 "	79.5 "	59.0 "
" 28	65.0 "	57.0 "	77.0 "	55.0 "
" 29	81.0 "	56.0 "	61.5 "	44.0 "
Total......	741.0 "	486.0 "	584.0 "	412.5 "

C. Collections from Fertilized vs. Unfertilized Cane

In the next series of experiments (J-1 to 4) two stools of H 109 cane, one fertilized and one unfertilized, and two stools of P. O. J. 2878 cane, one fertilized and one unfertilized, were used. This cane was planted on August 9, 1929, and fertilized on September 28, 1929, at the rate of 1,000 pounds per acre. The fertilizer contained 6 per cent N, 9.5 per cent P_2O_5 and 8.25 per cent K_2O. Attachments were made on May 28, 1930 (eight months after fertilization) and the amounts of root pressure liquids collected from these stools measured at 6:00 a. m. and 6:00 p. m. for 6 successive days, and at 6:00 p. m. for 5 additional days. Both of the H 109 plants were stools of 5 stalks each while the P. O. J. 2878 plants were stools of 6 stalks each. All stalks of each stool were cut "low" and connected to 250 ml. flasks. The amounts of liquids collected from these stools are recorded in Table VII.

TABLE VII

SHOWING THE AMOUNTS OF ROOT PRESSURE LIQUIDS COLLECTED FROM STOOLS OF FERTILIZED AND UNFERTILIZED H 109 CANE (5 STALKS EACH) AND STOOLS OF FERTILIZED AND UNFERTILIZED P. O. J. 2878 CANE (6 STALKS EACH) DURING 12-HOUR INTERVALS OVER A PERIOD OF 6 DAYS

1930	Time	J-1 (Fertilized H 109)	J-2 (Unfertilized H 109)	J-3 (Fertilized P. O. J. 2878)	J-4 (Unfertilized P. O. J. 2878)
May 28	6:00 p. m.	58.0 ml.(1)	13.0 ml.(1)	11.0 ml.(1)	36.0 ml.(1)
" 29	6:00 a. m.	280.0 " (2)	90.0 "	290.0 " (2)	74.0 "
	6:00 p. m.	150.0 "	56.0 "	146.0 "	97.0 "
" 30	6:00 a. m.	149.0 "	70.0 "	137.0 "	102.0 "
	6:00 p. m.	80.0 "	52.0 "	75.0 " (3)	76.0 "
" 31	6:00 a. m.	88.0 "	70.0 "	108.0 "	88.0 "
	6:00 p. m.	67.5 "	54.0 "	66.0 " (4)	80.0 "
June 1	6:00 a. m.	72.5 "	60.0 "	93.0 "	84.0 "
	6:00 p. m.	56.0 "	44.0 "	69.0 "	76.0 "
" 2	6:00 a. m.	65.0 "	49.0 "	77.0 "	76.0 "
	6:00 p. m.	52.0 "	41.0 "	45.0 "	74.0 "
" 3	6:00 a. m.	61.0 "	46.0 "	60.0 "	72.0 "
	6:00 p. m.	46.0 "	40.0 "	24.0 "	64.0 "
Total		1,167.0 "	672.0 "	1,190.0 "	963.0 "

(1) Not included in total.
(2) Flask was overflowing.
(3) Seven young shoots were observed developing from the base of this stool.
(4) The young shoots developing from the base of the stool cut off.

From these data it is seen that more liquid was collected at night than during the day. This was also indicated by the data of Tables V and VI. This can be seen by comparing any night reading with that of the succeeding day reading, or more easily when the data of Table VII are arranged as follows:

	J-1	J-2	J-3	J-4
Night (Total)	715.5 ml.	385.0 ml.	765.0 ml.	496.0 ml.
Day (Total)	451.5 ml.	287.0 ml.	425.0 ml.	467.0 ml.

A still more obvious indication of the data of Table VII is that more liquid may be obtained from fertilized cane than from unfertilized cane. During a period of 6 days a total of 1,167.0 ml. was obtained from the stool of fertilized H 109 as compared with 672.0 ml. from the unfertilized one. A total of 1,190.0 ml. was obtained from the fertilized P. O. J. 2878 as against 963.0 ml. from the unfertilized one. When in Table VII the individual readings for the fertilized stools are compared with those for the unfertilized ones, differences equally striking are seen.

IV. Chemical Analyses of Liquids

It is seen from the data of Table VII that by the technique used in Series J sufficient liquid for chemical analyses may be secured over night, or in twenty-four hours, from a single stool of cane. Stools of H 109 and P. O. J. 2878 cane both fertilized and unfertilized were used in the next series of experiments (L-1 to 4) in the same way as those of Series J-1 to 4. Attachments were made during the afternoon of June 9, 1930, and by the following morning quantities of these liquids sufficiently large for chemical analyses had been collected. Analyses were made of these liquids and also of those from Series I and J, the results of which are shown in Table VIII.

TABLE VIII

SHOWING CHEMICAL ANALYSES OF ROOT PRESSURE LIQUIDS FROM SERIES I, J AND L.

Results Expressed in Parts Per Million of Original Liquids.

Sample	pH	Total Solids	Loss Upon Ignition	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia and Albuminoid Nitrogen	Total Nitrogen	P_2O_5	K_2O	SO_4
I-1	5.11	1338	352	Nil	Nil	....	12.3	0.72	83.0	150.0
I-2	3.48	2037	528	"	"	....	5.0	1.05	130.4	70.0
J-1	5.11	2284	684	"	"	....	8.1	0.82	107.0	111.5
J-2	6.91	2242	898	"	"	....	4.2	0.57	105.1	50.5
J-3	4.92	2572	918	"	"	....	11.7	0.72	156.0	111.0
J-4	5.26	2464	1262	"	"	....	13.4	0.97	196.5	71.0
L-1	5.95	....	....	"	"	2.15	4.2	....	....	....
L-2	4.70	....	....	"	"	3.50	3.4	....	....	....
L-3	5.11	....	....	"	"	2.40	1.9	....	....	....
L-4	3.75	....	....	"	"	1.52	3.1	....	....	....

While Table VIII offers insufficient data from which to draw conclusions, several indications are of interest. The first of these is that, while ammonia is present, both nitrate and nitrite nitrogen are absent from these liquids. The liquid from the fertilized H 109 plant (J-1) contained more total solids but showed less "loss upon ignition" than did that from the unfertilized H 109 plant (J-2). The same was true for the liquid from the fertilized and unfertilized P. O. J. 2878 plants (J-3 and J-4 respectively).

From these data it can be seen further that the liquid from the fertilized H 109 plant (J-1) contained more total nitrogen than did that from the unfertilized plant (J-2). The same was true of the liquids collected from the fertilized and the unfertilized H 109 plants of L-1 and L-2 respectively. The reverse was true for the fertilized and the unfertilized P. O. J. 2878 plants, i.e., the liquid from J-3 contained less total nitrogen than that from J-4 and also the liquid from L-3 contained less than that from L-4.

In the J series the liquids from both the fertilized and unfertilized P. O. J. 2878 contained more total nitrogen than did those from both the fertilized and the unfertilized H 109. In the L series the reverse of this was true. When the

total of the figures of the four H 109 plants are compared with that of the P. O. J. 2878 plants it is seen that the total nitrogen for the former was 19.9 parts per million and, for the latter, 30.1 parts per million. Is this an indication that this P. O. J. variety is a relatively heavier nitrogen feeder than H 109?

The liquid from the fertliized H 109 plant (J-1) contained more P_2O_5 and K_2O than did that from the unfertilized plant (J-2). The reverse of this was true for the liquid collected from the P. O. J. 2878 plants (J-3 and J-4).

The liquids from both fertilized and unfertilized P. O. J. 2878 plants contained considerably more K_2O than did both fertilized and unfertilized H 109 plants, an average of 106.05 parts per million for the former vs. 176.26 parts per million for the latter. Is this an indication that the P. O. J. is also a relatively heavier potash feeder than the H 109?

The liquids from the fertilized plants of both varieties of the J series contained more sulphates than those from the plants of both varieties which received no fertilizer.

A. Composition of Root Pressure Liquids vs. Soil Analyses

On August 7, 1930, collection flasks were attached to 5 stools of H 109 cane (Series R-1 to 5). This cane was first ratoons, 16 months old. On July 8 and 9, 1929, it received 90 pounds of nitrogen, 90 pounds of phosphorus, and 60 pounds of potassium per acre. During May 4 to 24, 1930, it received 375 pounds of nitrate of soda per acre in the irrigation water. These flasks were removed on August 9, at which time soil samples (composite samples of four borings) were taken from beneath each stool. On August 19, 5 additional stools were treated in the same way (Series R-11 to 15). The purpose of taking these soil samples was to compare their analyses (1 per cent citric acid soluble) with those of the root pressure liquids. The chemical analyses of both soil samples and root pressure liquids are shown in Table IX.

From the data given in Table IX no conclusions can be drawn. No correlations seem to exist either between the amounts of plant foods in the soil from beneath the stool of cane, as determined by the citric acid method, and those present in the root pressure liquids collected from that stool, or between amounts of plant foods contained in the several specimens.

It is seen that there is less variation in the data for the soil analyses than in those for the analyses of the liquids. This greater variation in the composition of the liquids may be merely an indication of the fineness of the physiological reaction of the plant as compared with a chemical analysis. The differences of analyses of an adequate number of replications of root pressure liquids from one field as compared with those of liquids from another field might be more significant.

1. Prevention of Bacterial Contamination.

If permitted to stand at room temperature, these root pressure liquids soon became "milky" as the result of bacterial contamination. Unless their chemical

TABLE IX

SHOWING THE COMPOSITION OF ROOT PRESSURE LIQUIDS AS COMPARED WITH THE COMPOSITION OF SOIL (1 PER CENT CITRIC ACID SOLUBLE) TAKEN FROM BENEATH THE STOOLS FROM WHICH THE LIQUIDS WERE COLLECTED.

(Results Expressed in Parts Per Million of Original Liquid and of Water-free Soil.)

Series Number	Total Volume ml.	pH Soil	pH Liquid	Total Solids	Loss Upon Ignition	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia and Albuminoid Nitrogen	Total Nitrogen	P_2O_5 Soil	P_2O_5 Liquid	K_2O Soil	K_2O Liquid	CaO Soil	CaO Liquid	SiO_2 Soil	SiO_2 Liquid
R-1	600	..	..	1136	304	Nil	Nil	6.6	14.3	49	7.0	220	90	2280	66	1450	404
R-2	704	..	..	1182	398	"	0.18	2.9	11.8	48	13.2	130	106	2150	58	1010	332
R-3	949	..	..	1074	358	"	Nil	5.7	13.5	43	24.0	200	75	2360	67	1190	315
R-4	372	..	..	1127	563	"	"	9.8	18.2	39	17.2	210	71	2560	61	1360	209
R-5	462	..	..	1139	405	"	"	10.0	18.2	64	26.6	280	108	2480	54	1340	276
R-11	430	..	4.73	2184	1385	"	"	10.4	19.3	39	32.5	180	106	2340	81	1300	295
R-12	581	..	5.34	2039	1180	"	0.28	27.2	44.0	45	23.4	270	124	2550	58	1380	373
R-13*	9	..	5.26														
R-14† a.	794	..	4.68	1408	689	"	Nil	12.2	18.2		24.5		86		56		321
R-14†										42		100		2350		1250	
R-14† b.	675	..	4.48	1442	620	"	"	8.4	20.2		21.8		108		53		416
R-15*	132	..	4.85						5.6								

* Insufficient liquid for analysis.

† During the same collection period as for the others, a total of 1469 ml. of liquid was collected from this plant in two fractions.

analyses could be made immediately after collection, it was felt that some method of preventing contamination should be used. In collecting the liquids of Series R (Table IX), therefore, the collection flasks, connections of rubber tubing, Y-tubes, etc., were assembled in the field in such a way as to fit the number and arrangement of stalks of each of the individual stools before the stalks of the stools were cut. The ends of the Gooch tubing, which were to fit over the stumps of the cut stalks, were plugged with cotton. These flasks with their attached connections were then taken to the laboratory, wrapped separately in paper, autoclaved at 15 pounds pressure for 15 minutes, and then returned to the field to be attached as soon as the stalks of each stool were cut. When the stalks of the stool had been cut off immediately prior to attaching the autoclaved connections, the surfaces of the stumps were shaved off smooth with a sharp knife, flushed with a solution of bichloride of mercury and then with sterile, distilled water. The cotton plugs were next pulled from the ends of the Gooch tubing, which were quickly slipped over the ends of the stumps and tightly secured in place with rubber bands.

As a result of the above method the collected liquids were very clear and remained so for a much longer time than when these precautions were not taken.

Because an autoclave was not always at hand, a more convenient method of obtaining similar results was sought by collecting these root pressure liquids in flasks packed in ice, or from which light was excluded, or to which were added disinfectants or preservatives.

The next collections (Series Z) were made in this way. These attachments were made in the usual manner, i.e., the flasks, Y-tubes, and rubber tubing were washed thoroughly and rinsed with distilled water. The connections were assembled in the field at the time the attachments were made to the stools. Light was excluded by turning a light-proof box over the entire stool and its attached flask. Some of the collection flasks were packed in ice during the time the collections were being made. Toluene alone, and with chloroform, was added to some of the collection flasks. The liquids thus collected were brought to the laboratory and permitted to stand at room temperature for several days, after which the degree of their milky appearance as the result of bacterial contamination was recorded. The conditions under which these liquids were collected and their appearance after standing are recorded in Table X.

TABLE X

SHOWING THE CONDITIONS UNDER WHICH THE ROOT PRESSURE LIQUIDS OF SERIES Z WERE COLLECTED AND THE APPEARANCE OF THESE LIQUIDS AFTER STANDING FOR SEVERAL DAYS AT ROOM TEMPERATURE

Series Number	Treatment of Collection Flask During Collection: Light	Temperature	Preservative Added	Appearance of Liquid After Standing at Room Temperature
Z- 1	Not excluded	Air	5 ml. toluene	Very clear
Z- 2	" "	Ice	None	Slightly milky
Z- 3	" "	Air	"	Milky
Z- 4	" "	"	"	"
Z- 5	Excluded	"	"	"
Z- 6	"	"	"	".
Z- 7	"	Ice	"	Slightly milky
Z- 8	"	"	5 ml. toluene	Very clear
Z- 9	"	"	5 ml. toluene 5 ml. chloroform	" "
Z-10	"	Air	5 ml. toluene	" "
Z-11	"	"	5 ml. toluene 5 ml. chloroform	" "
Z-12	"	Ice	5 ml. toluene 5 ml. chloroform	" "

The results of this experiment indicate that the exclusion of light did not affect the degree of cloudiness of these liquids. The reduction of their temperature with ice resulted in some improvement, for the liquids thus collected were only slightly milky. By the use of toluene the best results were obtained. When toluene was added to the collection flasks, whether alone or with chloroform, whether the flask was in the dark or in the light, or whether the temperature was reduced or not, the liquids thus collected were always clear and sparkling. The fact that these liquids were equaled in clearness only by those collected after sterilizing the assembled connections, points to the conclusion that the milkiness of these liquids was due to bacterial contamination and to a disinfecting action of the toluene. When liquid paraffine was substituted for toluene the collected liquids became cloudy.

An analysis of these liquids is shown in Table XI.

TABLE XI

SHOWING IN PARTS PER MILLION THE COMPOSITION OF ROOT PRESSURE LIQUIDS OF SERIES Z

Series Number	Total Volume	pH Value	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Albuminoid Nitrogen	Total Nitrogen	Nitrogen in Entire Sample Grams	P_2O_5
Z- 1	1015	4.67	None	None	6.0	23.3	61.3	.0623	107
Z- 2	415	4.45	"	"	8.0	27.3	51.0	.0212	47
Z- 4	480	5.31	"	"	5.8	20.5	44.8	.0215	22
Z- 5	385	6.04	"	"	1.1	16.0	40.8	.0157	118
Z- 7	388	4.73	25 approx.	5.0	10.0	28.0	56.6	.0219	27
Z- 8	600	4.80	None	None	10.0	42.0	87.9	.0527	107
Z-10	375	4.75	"	"	7.4	23.0	52.7	.0198	35
Z-11	500	5.26	40 approx.	"	2.8	17.2	44.5	.0222	15
Z-12	425	4.60	40 approx.	"	6.6	15.8	51.8	.0220	33

Note:—Nos. 3, 6, and 9, duplicates of Nos. 4, 5, and 12 respectively, were not analyzed.

The next series of collections (AK–1 to 9) were made from three adjacent stools in the same line of each of three plots of cane, which on June 8, 1930, had received fertilizer as follows:

Collection No.	Fertilizer	Lbs. per Acre
AK–1 to 3	Sodium nitrate	1500
AK–4 to 6	Superphosphate	1500
AK–7 to 9	Potassium sulphate	6000

On February 26, 1931, all three of these plots received nitrogen at the rate of 100 (approximately) pounds per acre in the form of ammonium sulphate. The cane was planted on June 8, 1930, and the attachments were made on March 10, 1931. The first application of fertilizer was mixed with the soil in the bottom of the furrow immediately before the cane was planted.

The compositions of these liquids are shown in Table XII.

TABLE XII

SHOWING IN PARTS PER MILLION THE COMPOSITION OF THE ROOT PRESSURE LIQUIDS OF SERIES AK-1 to 9

Series Number	pH Values	Volatile Matter	Ash	Total Solids	SUGAR Sucrose	SUGAR Reducing Sugar	SUGAR Total	NITROGEN Nitrate Nitrogen	NITROGEN Nitrite Nitrogen	NITROGEN Ammonia Nitrogen	NITROGEN Albuminoid Nitrogen	NITROGEN Total Nitrogen	P_2O_5	K_2O	CaO	SiO_2
AK-1	4.65	2164	1350	3514	440	200	640	None	None	31	30	170	33	210	84	577
AK-2	4.64	2308	1258	3566	470	220	690	"	"	36	31	188	46	251	90	546
AK-3	4.58	2960	1264	4224	510	260	770	"	"	50	85	237	32	237	91	554
Average	*4.62*	*2477*	*1291*	*3768*	*473*	*236*	*700*	"	"	*39*	*48*	*198*	*37*	*232*	*88*	*559*
AK-4	4.70	3550	1068	4618	710	420	1130	"	"	46	97	247	57	216	84	491
AK-5	4.79	3086	1078	4164	650	330	980	"	"	47	98	236	33	152	84	505
AK-6	5.00	3082	1202	4284	820	320	1140	"	"	30	54	155	37	159	84	592
Average	*4.83*	*3239*	*1116*	*4355*	*720*	*350*	*1083*	"	"	*41*	*83*	*212*	*42*	*175*	*84*	*529*
AK-7	4.78	3912	1196	5108	1160	270	1430	0.11	"	39	70	232	38	234	66	512
AK-8	4.67	3031	1126	4157	760	290	1050	None	"	36	67	187	42	195	74	509
AK-9	4.72	3160	1094	4254	790	320	1110	"	"	30	66	188	34	202	64	491
Average	*4.72*	*3367*	*1139*	*4506*	*900*	*290*	*1196*	*0.04*	"	*35*	*67*	*202*	*38*	*210*	*68*	*504*
Average of AK—1 to 9	*4.72*	*3028*	*1182*	*4209*	*701*	*292*	*993*	*0.004*	"	*38*	*66*	*204*	*39*	*206*	*80*	*531*

Here again nitrates were notably absent, a trace being found in but one instance. Ammonia and albuminoid nitrogen were present. In some instances the variation of pH values, volatile matter, total solids, sugars, salts, etc., was remarkably slight while in others it was greater. How the variations in these data would compare with those in data of soil analyses, or how they would correlate with growth, or with amounts of sugar, cannot be said. The lack of such data renders an interpretation of the data of Table XII difficult.

Further comment will be made on these data under the discussion but, of course, it goes without saying that determinations of a sufficiently large number of replications should be made to make differences in the data significant.

V. Root Pressure as Measured by Mercury Columns

When open tubes six feet high were connected to stumps of cane stalks growing in the field, columns of liquid pumped up by root pressure, rose in them and overflowed from their tops and, when these 6-foot tubes were extended to a length of more than 10 feet, liquid, supported by root pressure, still rose in them and overflowed from their tops.

In the next series of experiments (Series P-1 to 6) mercury columns (manometers) were, therefore, attached to stools of the following varieties of cane: H 109, Lahaina, Yellow Caledonia, D 1135, Uba and P. O. J. 36 (Fig. 7).

The heights of each of these mercury columns were recorded every three hours throughout the day and night for a period of 21 days. In some instances, columns of mercury 138 cm. (1.9 atm.) high resulted. The height of such mercury columns is equivalent to that of water columns of more than 60 feet.

The readings for four of these plants are presented in graphic form in Figs. 8, 9, 10, and 11.

The readings presented in the graphs of Figs. 8, 9, 10 and 11 were taken simultaneously. The cane plants were of the same age, received the same amounts of irrigation water, and in every respect had received identical treatment. Weather data, including readings of maximum and minimum thermometers, wet and dry bulb thermometers, atmometer and rain gauge, were recorded.

In the curves of Figs. 8, 9, 10 and 11, there are several indications which seem to be significant. The first of these is that the root pressure rises at night and falls during the day. The highest pressure point occurred at about 9:00 a. m. and the lowest pressure point at about 3:00 p. m. This correlates with the data as recorded above (Tables V, VI and VII), which show that from the same stool of cane a greater amount of liquid was obtainable during the night than during the day; i.e., the greater quantity of liquid obtained during the night was the result of the increased night pressure.

A second indication is that irrigations resulted in increased pressure. The plants of this series received four irrigations during the 21-day period. The first two of these irrigations occurred on July 16 and 23 at 9:00 p. m. and 6:00 p. m., respectively. These two irrigations were made by running water into the cane rows at the rate of one inch per acre. Each of the other two irrigations was begun at 6:00 p. m. on July 26 and 27, respectively, and continued for a 12-hour period.

Fig. 7. Showing method of measuring the root pressure of cane plants by use of mercury columns. The connections with the manometer were bound with friction tape and copper wire. Rubber stoppers were, in the same manner, bound onto the cut ends of the stalks of the stool not attached to the manometer. Frequently these rubber stoppers were blown off in spite of their bindings.

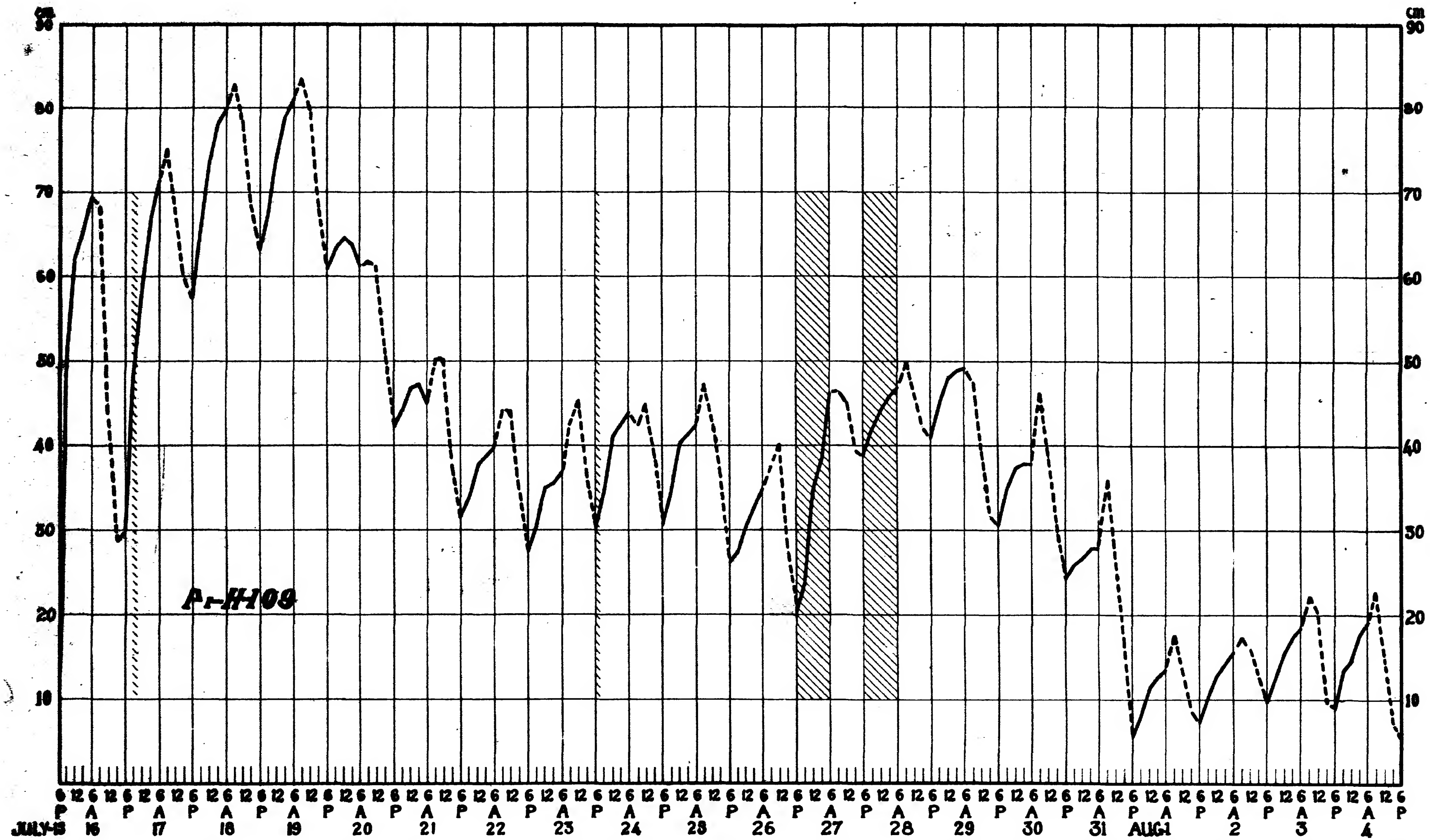

Fig. 8. Showing the root pressure of a cane plant of the variety H 109 (Series P-1) as measured in centimeters of mercury and recorded every 3 hours throughout the day (6:00 a.m. to 6:00 p.m.) and night (6:00 p.m. to 6:00 a.m.) for a period of 21 days.

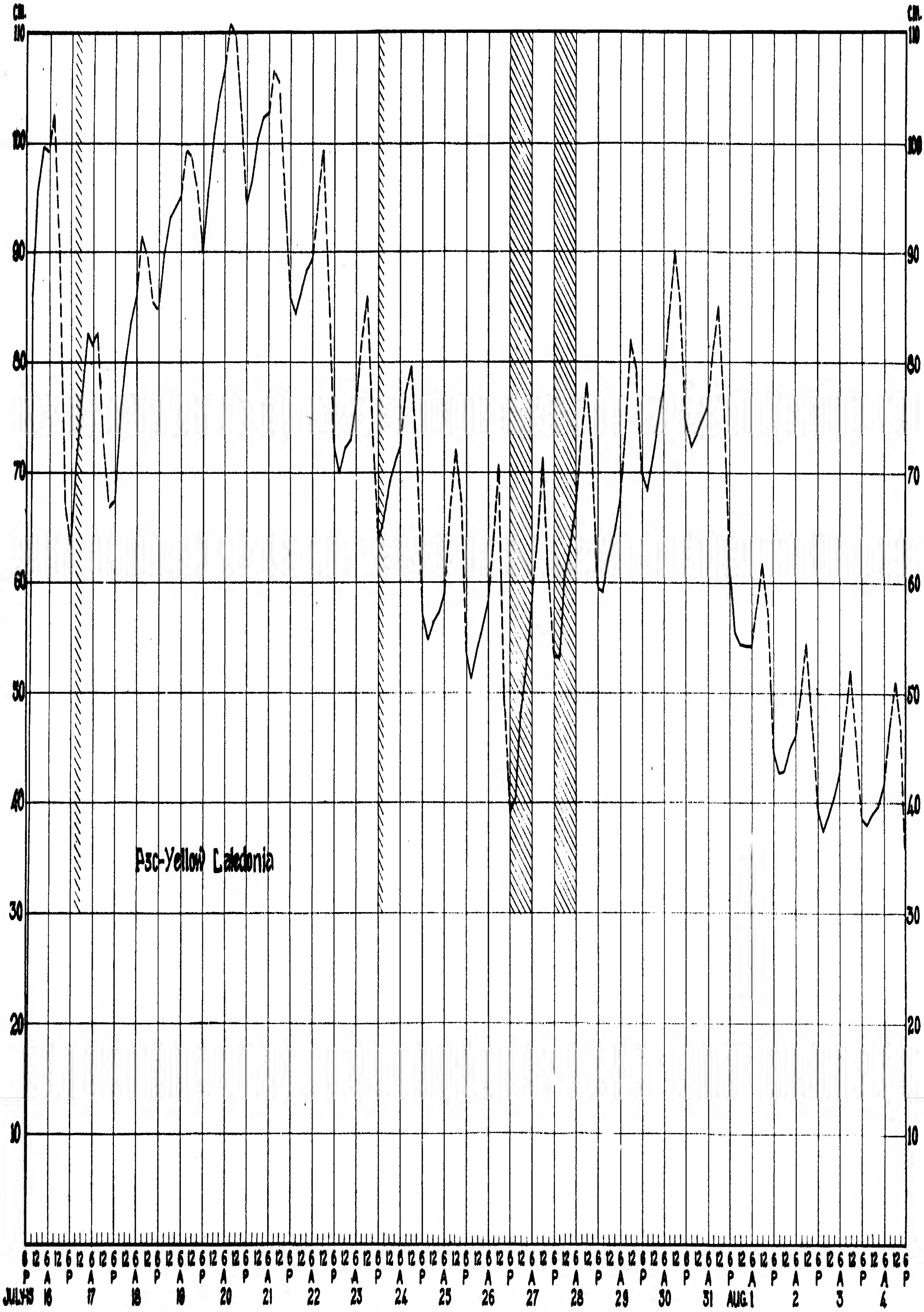

Fig. 9. Showing the root pressure of a cane plant of the variety Yellow Caledonia (Series P-3C) as measured in centimeters of mercury and recorded in the same manner as that of the H 109 plant recorded in Fig. 8.

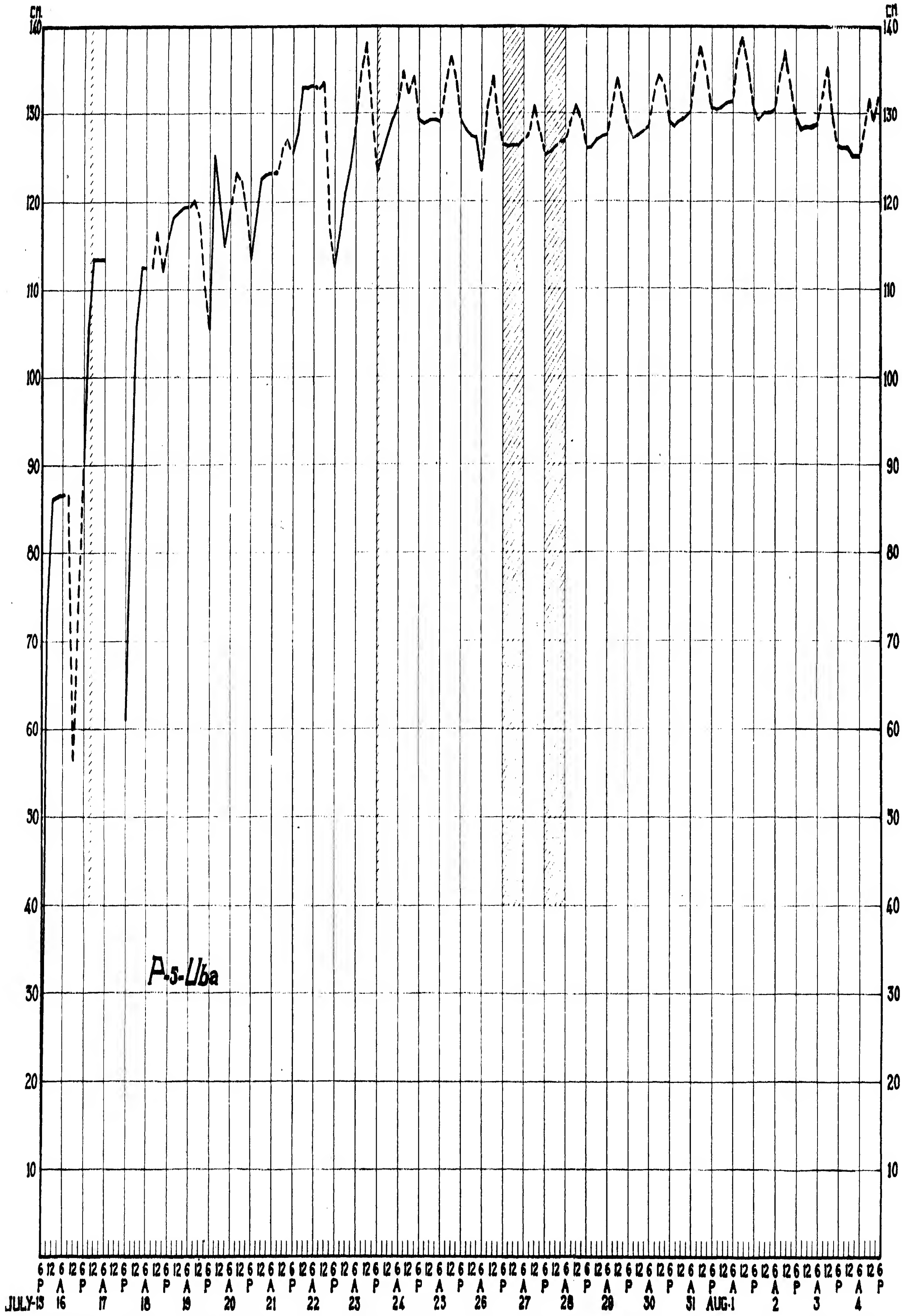

Fig. 11. Showing the root pressure of a Uba cane plant (Series P-5). Record made simultaneously with those of the varieties shown in Figs. 8, 9 and 10.

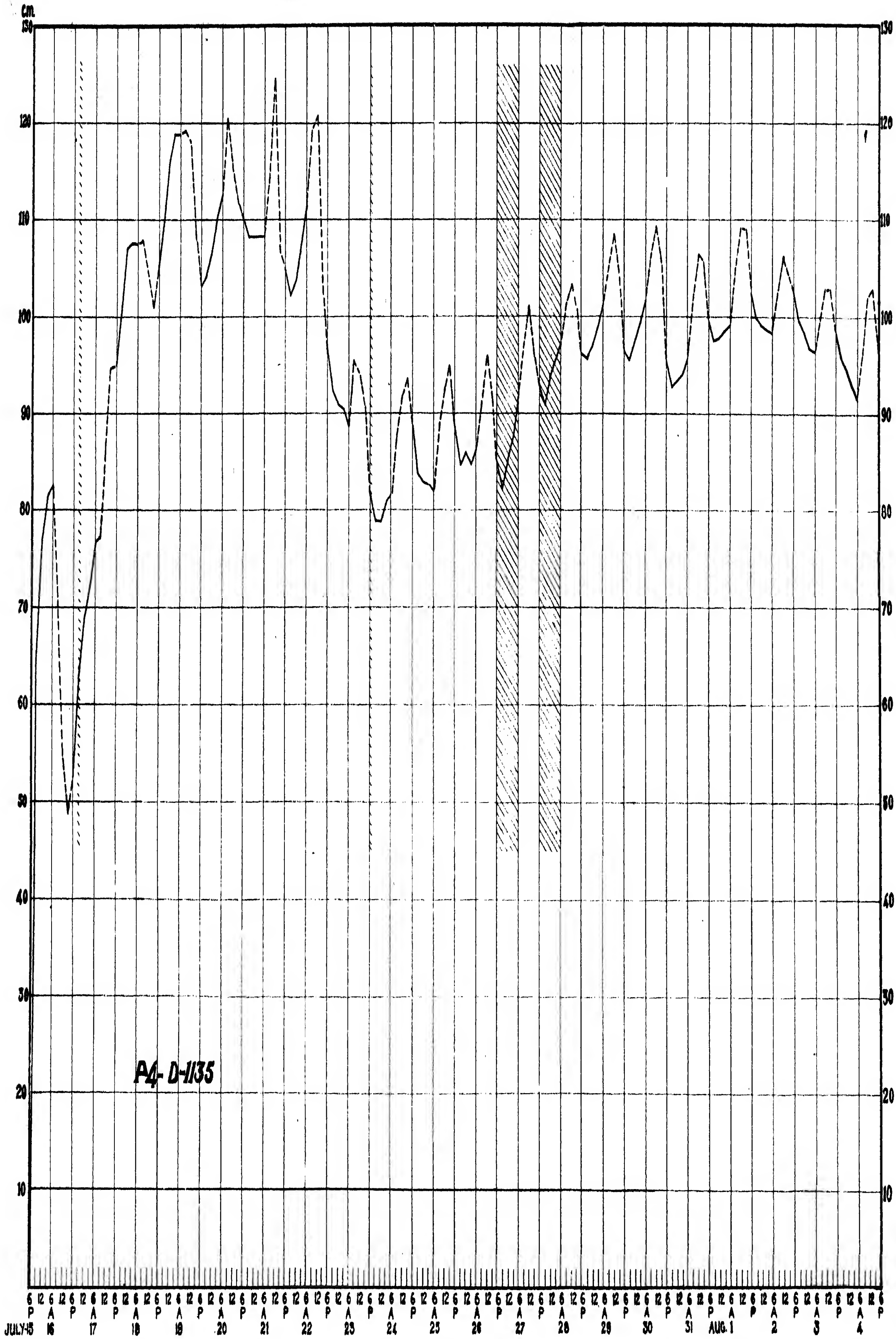

Fig. 10. Showing the root pressure of a cane plant of the variety D 1135 (Series P-4). Record made simultaneously with those of the H 109 and Yellow Caledonia plants recorded in Figs. 8 and 9, respectively.

These latter irrigations were made by the use of lawn sprinklers at a rate which would, during the 12-hour period, somewhat approximate the same amount of water as was applied in the first two irrigations. These irrigations are indicated in Figs. 8, 9, 10 and 11 by cross hatching.

The recorded weather data show that during the 21-day period the rainfall was little more than a "trace" so that the effects of the irrigations on the recorded root pressures were not obscured by water from another source.

It is seen from the graphs of Figs. 8, 9, 10 and 11 that, following the first irrigation on July 16, there was an increase of pressure for each of the four varieties. This first irrigation was purposely withheld until the pressure had passed the first high-pressure point at 9:00 a. m. and was building up again after the low-pressure point at 3:00 p. m. on the day following the attachments.

Following the irrigation of July 23 less increase of pressure was seen than following the first one. This second irrigation was withheld until the pressure had somewhat subsided but, perhaps, this lack of response indicates that water was withheld too long.

Following the 12-hour irrigations by lawn sprinklers definite responses were seen for the H 109, the Yellow Caledonia and the D 1135. It may be interesting to note that, while the amounts of water used in these latter irrigations were no greater than those of the first two, the prolongation of the irrigations resulted in a significant response even after the second irrigation had failed to do so.

When water was withheld long enough the mercury columns of the manometers gradually descended to and crossed the zero point, thus registering negative pressure. As much as —54 cm. of mercury have thus been registered by a plant growing in the field (Fig. 12).

A still more significant indication may be seen by a comparison of the graphs of Figs. 8 to 11. Because of the bearing it may have on varietal variation in respect to drought resistance, this indication, if consistent for a large enough number of plants of each of these varieties to be established as fact, will be of the first importance.

It is seen from the graphs (Figs. 8 to 11) that, as compared with those of the Yellow Caledonia, D 1135 and Uba plants, the pressure for the H 109 plant throughout the 21-day period was considerably lower. The maximum pressure attained by the H 109 plant was 83.4 cm. at 9:00 a. m. on July 19. At 6:00 p. m. on the last day of the 21-day period this pressure had dropped to 5.7 cm. As compared with that of the other three varieties, not only was the maximum pressure of the H 109 plant lower but the pressure finally dropped to a lower point when irrigations were withheld.

Throughout the 21-day period the pressure of the Yellow Caledonia plant was consistently higher than that of the H 109 plant. A maximum pressure of 110.9 cm. was attained at 9:00 a. m. on July 20, which at 6:00 p. m. on the last day of the 21-day period had dropped to 36.0 cm. As compared with those of the H 109 plant greater responses to the irrigations were seen.

The pressure of the D 1135 plant was not only higher throughout the 21-day period than that of the H 109 plant but exceeded that of the Yellow Caledonia plant as well. At 12:00 m. on July 21 a pressure of 124.5 cm. was attained,

Fig. 12. Showing that when water was withheld from a cane plant (Fig. 9), the mercury column measuring its root pressure descended to, crossed and descended 53.5 cm. below the zero point, thus registering negative root pressure. Readings recorded at 9:00 a.m., 12 m., and 3:00 p.m. only for these dates.

Fig. 13. Showing method of studying direct effects of various forms and amounts of liquids and gases, plant foods, enzymes, vitamines, disinfectants, stimulants, etc., when thus introduced "hypodermically" into stools of growing cane.

which at 6:00 p. m. on August 4 had dropped to 96.4 cm. The responses of this D 1135 plant to irrigation were even more pronounced than were those of the Yellow Caledonia plant.

In the case of the Uba plant we see exhibited the highest pressure of the four plants. At 12:00 m. on July 23 a pressure of 138.8 cm. of mercury was attained and virtually maintained throughout the remainder of the 21-day period. This

height of mercury is equal to a pressure of 1.8 atmosphere, or 26 pounds per square inch, and is equivalent to a column of water 60 feet high.

In the graphs of Figs. 8 to 11 it is seen that there is an indication of a direct correlation between the root pressure of these varieties and their drought resistance.

VI. "Suction Feeding"

Another phase of this work was suggested when a tube filled with a solution was attached to but one cut stalk of a stool and all of the other stalks of the stool were left growing. Because of the underground connections with this stalk, the stalks of the stool left uncut could, as the result of "leaf pull," draw away from the cut stalk the liquid which might otherwise collect in the attached tubes. No head of liquid resulted in the case of such attachments but water had to be added each day to the tube because the level of the liquid had always sunk below an established zero point. Burettes were attached instead of glass tubing and filled with water. After several hours these burettes were empty. (Fig. 13.)

The idea of using this technique as a means of studying the effects of various forms and amounts of liquids and gases, salts, enzymes, vitamines, disinfectants, stimulants, etc., when introduced directly into stools of growing cane naturally suggested itself.

While this injection method has not yet been developed, several experiments in which it was used might be suggestive.

Four solutions of nitrate of soda containing 10, 100, 250, and 500 p.p.m. of nitrogen were used. Two stools of H 109 cane were "injected" with each of these solutions. The burette was attached to the primary stalk of each stool of cane and kept filled for 5 days, after which time the amount of the solutions drawn into each plant was determined.

At the same time four solutions of ammonium sulphate containing the same number of p.p.m. of nitrogen as the four solutions of nitrate of soda were used to inject eight other stools of H 109 cane (two stools with each solution).

This H 109 was five months old, plant cane. It had received no fertilizer whatsoever and was of a very yellow color.

The average amounts of these liquids taken in by each of these stools are shown in Table XIII.

TABLE XIII

SHOWING THE AMOUNTS OF NITROGEN IN GRAMS TAKEN IN BY STOOLS OF FIVE MONTHS OLD H 109 CANE IN A 5-DAY PERIOD BY THE "SUCTION-FEEDING" METHOD FROM SOLUTIONS OF NITRATE OF SODA AND AMMONIUM SULPHATE

Solution	p.p.m. Nitrogen in Solution	pH of Solution	Ml. Solution Injected	Grams Nitrogen Injected
Nitrate Soda	10	5.7	139.0	0.00139
" "	100	5.7	285.0	0.02850
" "	250	5.9	269.5	0.06737
" "	500	6.5	234.5	0.11725
Ammonium Sulphate	10	5.9	80.0	0.00080
" "	100	5.7	76.0	0.00760
" "	250	5.8	30.0	0.00750
" "	500	5.8	76.5	0.03825

From these data it is seen that more nitrogen was taken in in the form of nitrate of soda than in the form of ammonium sulphate. There seemed to be no correlation between the amount of solution taken in and the pH of the solution. In several days after the injections these plants began to show a greener color than the plants in adjacent rows which had not been injected. After several weeks these plants, especially those which had received the greater amounts of nitrogen in the form of nitrate of soda, were of a decided green color and of a larger size as contrasted with the untreated plants.

VII. Discussion

The phenomenon of the exudation of liquid as the result of root pressure, such as has been described in the above experiments, is common to many plants. Priestley and Wormall (6) state that: "Wieler, (7), in 1893, gave a list of 126 species of 93 genera drawn from Filices, Gymnosperms, Monocotyledons and Dicotyledons, reported by previous workers on what seemed to him unexceptional grounds; from his own observations he added another 58 species from 47 genera of vascular plants, including Equisitum."

The cause of this phenomenon, i.e., the mechanism of root pressure, is not fully understood although much has been written about it (2), (4), (5), (and literature cited).

Priestley and Wormall (6) also state: "The chemical nature of the exudates frequently obtained in considerable quantity from the root system of a plant is a subject of considerable importance in relation to many problems of plant physiology, and it is a matter for surprise that more definite data are not available in the literature."

If the composition of the root pressure liquid of a plant can be interpreted as an indication of what has been absorbed by the plant from the soil in which it is growing, an index can be had of what is *available* to the plant from that soil and there will at once be at hand a better method of approaching the nutritional problems of that plant.

Despite their general use, certain objections are raised to chemical methods whereby the amounts of plant foods in an extract of a soil are determined. These extracts may be made by any one of a number of chemicals such as citric acid, hydrochloric acid, acetic acid, etc. The principal objection to such methods is the interpreting of the amounts of plant foods so extracted as an index of their *availability* to the plant.

Objections can be had to these methods also because the soil is usually taken from some particular horizon, the first foot, for example. Whatever correspondence exists between this distribution of the roots and the distribution of their feeding surfaces, it is certain that root pressure liquids are absorbed through these feeding surfaces wherever they are in contact with the soil as a result of the natural distribution of the root system in the soil. The lateral spread and depth of such a root system varies, of course, with the variety and age of cane, character of soil, etc., but no system of soil sampling could possibly be so representative as this natural root distribution. In connection with such methods as those

of Mitscherlich, Neubauer, Winogradsky, etc., the question always arises as to the agreement of the plant foods required by the indicator plant with those of the plant under consideration. Some object to the size of the artificial containers used by these methods.

In the use of root pressure liquids these objections, at least, would be eliminated because the very plant under consideration is being used in its natural environment, i.e., the cane plant growing under normal conditions in the cane field.

It should at least be proved, therefore, whether or not the composition of root pressure liquids collected from the cane plant growing under normal conditions offers a more satisfactory method of determining the requirements or deficiencies of plant nutrients of the cane plant.

A. Technique of Collection

It was apparent that the first requisite for accomplishing the objective of the present research was the development of a method of collecting root pressure liquids in amounts large enough for chemical analyses. A technique was finally arrived at of simply cutting off all of the stalks of a stool and, by means of Y-tubes and rubber hose connections, collecting the liquid from the total number of stalks of the stool.

It was demonstrated that more liquid was collected at night than during the day (Tables V and VII), the explanation of which was found later in the experiments on root pressure which demonstrated a rising pressure at night and a falling pressure during the day. This, of course, does not explain why the root pressure was higher at night than during the day but indicates that the amount of liquid collected during the night was greater than that collected during the day simply because of the increased night pressure.

In the earlier experiments, especially the ones preceding those of Series G, where but one stalk of a stool was cut, it will be remembered that sometimes liquid, as the result of root pressure, could be obtained while at other times it could not. More often water, which had been added to the attachment, was drawn into the stool of cane. This is interesting because its explanation may be found in an indicated "balance," or ratio, between the totals of the complementary forces of root pressure and leaf pull.

A possible explanation of the apparent irregularity in the behavior of these earlier experiments may be suggested in that, when but one stalk of a stool was cut, liquid was collected as the result of root pressure, in relation to the leaf pull, being relatively higher; if the leaf pull, in relation to the root pressure, was relatively higher, negative, or suction pressure resulted. When two stalks of a stool were cut, the average amount of liquid collected per stalk per unit of time was greater than when but one was used because the ratio of these two forces was upset still further in favor of the root pressure. As the number of stalks cut per stool was increased, the amount of liquid collected per stalk per unit of time was increased.

Also, depending upon the amounts of moisture in air and soil, the water content of the cells of the plant may be lowered. The difference between this lower amount and the total amount of water a cell is capable of absorbing is known as the

"saturation deficit."* The amount of the saturation deficit depends upon how much the transpiration from the leaves was in excess of the supply of water from the roots. Saturation deficit, then, either separately, or in relation to leaf pull, may also play a part in the above explanation. Certainly as the number of stalks cut per stool was increased, the saturation deficit was decreased.

What differences in the composition of liquids collected from stools of cane with all of the stalks cut as compared with the composition of liquids from stools with one or more stalks left growing was not determined.

From the graphs of Figs. 8 to 11 it is seen that, on successive days after the manometers were attached, the root pressure of the stool of cane gradually decreased. The data of Tables V and VII correlate with these curves in that, on successive days after the collection flasks were attached, the amounts of liquids collected diminished. This correlation explains why, when only one stalk of a stool was cut, liquid was sometimes collected for a day or so and then water had to be added to bring the level of the liquid up to the established zero point.

In the data of Table VII is seen a rather definite indication that larger amounts of liquids may be collected from plants which have been fertilized than from plants which have not. It would be interesting to determine whether this larger amount was due simply to an increased root mass, as the result of the fertilization, to a stimulation of physiological function, or to both.

It was seen that greater amounts of liquids were collected from stools of cane with the stalks cut "low" than from stools of cane cut "high." In the experiments of Series I-1 and I-2, for example, 1962.0 ml. of liquid were collected from the stool with the stalks cut "low" as compared with 1521.0 ml. from the stool with the stalks cut "high," a difference of 441.0 ml. How much of this difference was due simply to a difference of hydrostatic pressure as a result of the stalks of I-2 being 60 cm. higher than those of I-1, and how much was due to the fact that this liquid was absorbed by the cells of the cane stalks, is no doubt capable of determination.

B. Chemical Analyses of Liquids

When the data of the analyses of these root pressure liquids are examined one sees certain clear-cut indications. From the data of Tables VIII, IX, XI, and XII, it is seen that nitrate nitrogen and nitrite nitrogen are practically nil in these liquids. This fact explains, no doubt, why Hoffer's (3) test for nitrate nitrogen made by applying diphenylamine to the tissues between the nodes of freshly cut corn stalks was always negative when applied to cane. It would be interesting to apply this test here in Hawaii both to cane and to corn plants growing in the same soil heavily fertilized with nitrogen and also to compare the composition of the root pressure liquids collected from both the cane and the corn plants.

The absence of these two forms of nitrogen is interesting also in connection with eye spot disease because it was once thought that the degree of severity of an attack of eye spot was due to the presence of nitrate nitrogen in the tissues of the plant. Because the severity of an attack of eye spot can effectively be con-

* The author is indebted to Dr. Chas. A. Shull of the University of Chicago for the expression "saturation deficit."

trolled by withholding applications of a fertilizer containing nitrogen for several months preceding the eye spot season, the question arises as to whether the severity of the attack is due to the form, or to the amount of the nitrogen contained in the tissues of the plant; or whether it is due to the conditions of the tissues due to rapid growth as a result of the fertilization.

In Tables XI and XII it is seen that the albuminoid nitrogen exceeds the ammonia nitrogen by several times. The only exception to this was in the case of AK-1 to 2 (Table XI) where these liquids were collected only 12 days after an application of 100 pounds of nitrogen per acre in the form of ammonium sulphate. Here the ammonia nitrogen slightly exceeds the albuminoid nitrogen and the ratio of ammonia nitrogen to albuminoid nitrogen is considerably less for the average of the three plants (AK—1 to 3) as compared with the rest of the plants (AK—4 to 9), which received phosphorus and potassium along with the nitrogen.

In the AK series the amounts of total nitrogen contained in the liquids from the first plot (AK-1 to 3) would be expected to be greater than the amounts contained in the liquids from the other two plots because it had had a larger application of nitrogen (having received $NaNO_3$ at the rate of 1500 pounds per acre on June 8, 1930, and ammonium sulphate at the rate of 448 pounds per acre on February 29, 1931). This, however, was not the case; the greatest amount of total nitrogen having been taken up by the plot which had received the application of phosphorus in addition to the application of nitrogen. Also, the amount of total nitrogen taken up by the plot which had received an application of potassium in addition to the nitrogen application was greater than that taken up by the plot which had received two applications of nitrogen. At first these data seem contrary to what might be expected but, perhaps, the story they may have to tell requires interpretation. It may be possible that more nitrogen was taken up in the second and third plots because the addition of a second salt (phosphorus to the second plot—AK-4 to 6—and potassium to the third plot—AK-7 to 9) resulted in greater growth and a greater uptake of whatever was present in the soil as a result of amounts of plant foods being available in more nearly optimum ratios. If this be true, the addition of any single salt above a certain amount would for the time being, at least, be wasted. Better economy would be the "salvaging" of this additional amount (either at once or later in the plants' development) with applications of other plant foods which would make it available.

In the case of the second plot, which was the only plot receiving an application of phosphoric acid, the liquids showed the highest amount of phosphoric acid. In the case of the third plot, which was the only plot to receive potash, the amount of potassium present in the liquids was less than in those from the plots which had received the nitrogen. Such facts as these are difficult to understand.

The amounts of lime and silica taken up by the individual plants in all the plots were remarkably uniform. The amounts of silica taken up in the plot which had received the nitrogen application were highest. This agrees with work done by Ayres (1), who showed that there was ~~a~~ correlation between the uptake of silica and the amount of nitrogen applied.

When the amounts of N, P, and K in these liquids from different fields are

compared, greater differences are seen between fields than between individual stools in the same field. This is apparent when the averages of these elements in all specimens collected are arranged as follows:

Place	Series	No. of Collections	Age of Cane, Months	Number Months After Fertilization	p. p. m.		
					N	P_2O_5	K_2O
Pathology Plot	I, J, L	10	9	8	6.73	0.80	129.66
Oahu Sugar Co., Field 55	R	10	16	13 (N, P, K); 2.5 (N)	18.33	21.13	97.11
Experiment Station Grounds	Z	10	8	......	23.65	56.77	.....
Waipio Substation, Field 27	AK	9	9	9 (N, P, K); 12 (days) (N)	204.44	39.11	206.22

Because the results of these analyses have been so varied, attempts have been made to standardize a method whereby the significance of the analyses of these root pressure liquids would be made apparent. These attempts were made in sand cultures in which plants were grown with high phosphorus vs. low phosphorus, all other elements of the culture solution remaining the same.

So far these attempts have not netted amounts of liquids as large as desirable for chemical analyses but attempts to increase the amounts of these collections are being continued.

It is planned to compare amounts of various elements, or ratios of elements, taken up by different varieties of cane plants grown in culture solutions containing low amounts vs. high amounts of, or various ratios of, the elements in question. These amounts and ratios can then be compared with the growth of the plants, with the amounts of sugar in these root pressure liquids, and with the amounts of sugar produced by each individual plant.

C. Carbon-Nitrogen Ratios

When the ratio of the total nitrogen to total sugar is studied in the data of Table XII some very suggestive correlations are seen. They are shown in the following table:

Series Number	Total Nitrogen	Total Sugar	Ratio	Fertilizer
AK—1	170	640	1:3.7	NN
AK—2	188	690	1:3.6	"
AK—3	237	770	1:3.2	"
AK—4	247	1130	1:4.5	PN
AK—5	236	980	1:4.1	"
AK—6	155	1140	1:7.3	"
AK—7	232	1430	1:6.1	KN
AK—8	187	1050	1:5.6	"
AK—9	188	1110	1:5.9	"

From these data it is seen that the ratio of nitrogen to sugar is greater in the liquids from the plants which had received both phosphorus and nitrogen than from the plants which received only nitrogen; and in those liquids from the plants which had received potassium and nitrogen, it was the highest of all. These data suggest a possible approach to the study of cane ripening and juice quality.

D. Night vs. Day Pressure.

The question as to why greater root pressure was manifested by cane plants at night than during the day cannot easily be explained. At first it was surmised that during the day greater evaporation from the surface of the soil or, that during the day, the transpiration from adjacent plants whose roots were interlaced with those of the cut stool, was responsible for this difference. But stools of cane which were isolated in concrete pots and which had developed from single eyes exhibited the same differences of day and night pressure. Plants in sand cultures, in which very little difference of day and night temperature existed, behaved in the same way. If differences of day and night temperature could be responsible for these differences of day and night pressure, the low pressure would be expected to exist at night and the high during the day. But the very reverse of this exists. Stools of cane covered with light-proof boxes also manifested these day and night differences.

With the data in hand the only suggestion that can be made is that it is the manifestation of a plant habit persisting even after the rhythmical stimulus has been removed and that this stimulus is associated with the force of "leaf pull" caused by rhythmical day vs. night transpiration, or with light and darkness.

In Hawaii, the H 109 is a variety of cane which requires irrigation for successful culture. It is thought of as an "irrigated" cane in contrast with those varieties which, because they do well under unirrigated conditions, are termed "dry land" canes. The term dry land cane used in this respect is apt to be misleading because these canes are grown under conditions varying, according to season, from heavy rainfall to drought. All do better under irrigated conditions but with irrigations H 109 will excel them. Under dry conditions they will excel H 109. Yellow Caledonia, D 1135, and Uba are varieties of these dry land canes exhibiting different degrees of drought resistance. Yellow Caledonia, while requiring more water than D 1135, is thought of as being more drought resistant than H 109, D 1135 more drought resistant than Yellow Caledonia, and Uba as the most drought resistant of all.

E. "Suction Feeding."

The method of "Suction Feeding" offers a technique for studying the effects of various forms and amounts of liquids and gases, salts, disinfectants, stimulants, etc., when introduced directly into the stool of growing cane. By attaching tubes of varying lengths, or by elevating reservoirs to different heights, different hydrostatic pressures may be secured for forcing such liquids into the stools.

What would be the effect on the susceptibility of a stool of cane to eye spot, for instance, into which had been injected varying forms and amounts of nitrogen? The susceptibility of cane to eye spot is reputed to be due to the presence of *nitrates* in the leaves and yet the chemical analyses of these root pressure liquids

show nitrate nitrogen to be totally absent. Is this absence due to nitrogen being changed in the soil to some other form than nitrate before being absorbed by the roots, or is nitrogen absorbed as nitrate and changed *within* the roots after absorption? What would be the effect on growth of the cane plant of nitrogen *within the plant in the form of nitrates?* What would be the effect on the percentage of germination, stand of cane, and final yield from cuttings from stools of cane into which had thus been injected various plant foods or stimulating chemicals? Could mosaic disease be transmitted by injecting into healthy plants liquids thus forced out from the stems and leaves of diseased plants?

VIII. Summary

1. Experiments designed to approach the plant food requirements of sugar cane plants growing under field conditions through the analyses of their root pressure liquids are reported.

2. Two techniques of collecting these root pressure liquids under sterile conditions were developed.

3. Chemical analyses of root pressure liquids collected principally from H 109 cane in a number of different fields were made for pH value, total solids, loss upon ignition, nitrate, nitrite, albuminoid and total nitrogen, P_2O_5, K_2O, SO_4, CaO, SiO_2, etc.

4. Because of the variance found to exist between the composition of these liquids and the composition of the soil (1 per cent citric acid), attempts are being made to interpret such discrepancies.

5. This method consists of comparing the amounts of various elements, or ratios of elements, contained in the collected root pressure liquids with those in culture solutions in which the plants are grown.

6. While ammonia and albuminoid nitrogen were present, both nitrate and nitrite nitrogen were notably absent from these liquids.

7. The quantity of liquid collected at night (6:00 p. m. to 6:00 a. m.) exceeded the amount collected during the day (6:00 a. m. to 6:00 p. m.).

8. These larger night quantities can be explained by the fact that the root pressure was higher at night than during the day.

9. Greater amounts of liquids were collected from stools of cane which had been fertilized than from stools which had not.

10. Columns of liquid as the result of root pressure filled and overflowed tubes more than 10 feet high.

11. The height of mercury columns (manometers) attached to stools of H 109, Lahaina, Yellow Caledonia, D 1135, and Uba cane were read every three hours throughout the day and night for a period of 21 days.

12. Columns of mercury as high as 140 cm. resulted, which height corresponds to water columns of more than 60 feet high.

13. When presented graphically the night readings show a rising curve while the day readings show a descending curve. The fact that higher pressures exist at night than during the day explains why greater quantities of liquid are obtainable during the night as compared with the amount obtainable during the day from the same stool of cane.

14. When irrigations were withheld from Uba, D 1135, Yellow Caledonia, and H 109 the falling off of the pressure curves over a 21-day period was greatest in the case of H 109, less in the case of Yellow Caledonia, still less in the case of D 1135, and least in the case of Uba. Listed in the order of the pressures maintained, these canes were in order of their drought resistances, namely, Uba, D 1135, Yellow Caledonia and H 109.

15. A burette filled with solution was attached to a single stalk of a stool of cane. Because of the underground connections with this stalk, the stalks of the stool left uncut, as the result of "leaf pull," drew into the body of the plant the solution in the burette.

16. This technique of "suction feeding" suggests a method of studying direct effects of various forms and amounts of liquids and gases, plant foods, enzymes, vitamines, disinfectants, stimulants, etc., when thus introduced "hypodermically" into stools of growing canes.

Sincere thanks are due first of all to the colleagues of my own department for their quick appreciation of the possibilities suggested by this work, to the head of the chemistry department and his associates for their ready cooperation in making the chemical analyses, to the sugar technology department for the sugar analyses, to many others whose enthusiasm was encouraging, and by no means least to my two faithful helpers who so willingly made the night readings and took care of the general details.

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A Report on the Local Use of Student's Method

By O. H. Lyman

The following report has been drawn covering the main points with additions, examples, and explanations, of a series of discussions held recently at the Experiment Station concerning Student's Method of plot yield analysis in comparison with other methods.

Purpose of Mathematical Studies of Harvest Data

In past years and in many cases today our experimental work with field tests has been given over to determining large responses due to the application of one plant food or another. Today we know without a doubt that nitrogen must be applied, that certain soils produce tremendous returns from phosphate additions, and still other soils yield us handsome profits from potash applications. With these facts established, we are left today with the task of determining the most profitable amount and time of applying these increases. The differences in yields become much smaller and increasingly more difficult to ascertain as we decrease the treatment variable. To obtain information as to the significance of these small differences we must turn to our mathematicians, who give us a number of methods, among others, the probable Error of the Mean Method, and Student's Method.

Comparison of Methods

In the "P. E. of the mean" method we have a measure of the reliability of the mean. This measure is represented by a figure immediately preceded by a plus and minus sign ($\pm$) following the average or mean under consideration, as 75 ± 2.5, the 2.5 being the probable error of 75. This figure defines the range through which the average or mean may be expected to vary. Thus, if we harvest 10 plots, the mean yield of which is 60 tons, with a P. E. of this mean of 5 tons, (written 60.0 ± 5.0), we understand that if a large number of similar tests were run under conditions neither more nor less variable than those of this particular test, their means may be expected to fall between 55.0 (60—5) and 65.0 (60+5) tons in 50 per cent of the trials.

By referring to a table of odds derived from the normal probability curve, we can draw still further conclusions. The table of odds tells us that departures of twice the probable error may be expected to occur by chance once in 5.64 times. In the case under consideration, with its mean of 60 and its P. E. M. of 5, we understand that if this test were to be repeated many times under conditions neither more nor less variable than those of this test, the mean may be expected to fall between 50 (60—2×PE) and 70 (60+2×PE), 4.64 out of 5.64 times or about

82.3 times in a hundred. Similarly by again referring to the probability table, we can determine the chances of departures of three times the probable error, or of any other magnitude in which we may be interested.

To determine the P. E. of a difference between the means of two treatments A and B, we must first know the P. E. of the mean of A and the P. E. of the mean of B. The P. E. of the difference between these two means is equal to the square root of the P. E. of the mean of the A series squared, plus the P. E. of the mean of the B series squared.

$$PE_{M_A - M_B} = \sqrt{(P.E._{MA})^2 + (P.E._{MB})^2}$$

It should be noted, however, that the above formula is correct only when there is no correlation* between the plots of the A series and those of the B series. In a well laid-out field test, we may expect a fair correlation between the two series. The correlation may become marked when there is a fertility slope. In such an event, the coefficient of correlation must be calculated and used in arriving at the P. E. of the difference as indicated below:

$$PE_{M_A - M_B} = \sqrt{(P.E._{MA})^2 + (P.E_{MB})^2 - 2r_{AB} \times P.E._{MA} \times P.E._{MB}}$$

where r_{AB} represents the coefficient of correlation between the A and B series.

Student's Method

In Student's Method we have also a measure of reliability vested in a figure termed odds following the differences in the averages of the two paired treatments. Conventionally, odds approaching the arbitrary figure 30 to 1 or above are considered reliable. In other words, the chances of reproducing this gain or loss indicated are good when odds approaching 30 to 1 or more are recorded. It has been rightly stated that the figure representing odds with Student's Method is worth fully as much in the final analysis of the result secured as the difference between the treatments compared. In other words, the odds gives us a simple term on which to evaluate the reliability of the difference secured in the averages.

As has been stated, 30 to 1 odds is an arbitrary rating for reliability. Odds somewhat below this may give us reliability depending upon the magnitude of the differences and the number of comparisons. We should keep in mind the meaning underlying the odds figure, i.e., odds of 10 to 1 mean to us that in eleven trials the chances are that the difference noted between treatments would not occur more than once in eleven times where no variable treatment was applied as in a blank test where the variation is due entirely to soil. We feel that odds of 10 to 1 are too low for reliability so have raised our standard for security.

In Student's Method, we are able to pair off individual plots lying in similar

* By correlation is meant the tendency for the variables (in this case the varieties or treatments under test) to vary together rather than independently. Thus, all treatments or varieties tend to give yields higher than their averages in the best section of the experimental area, and lower than their averages in the poorest section.

conditions (plots adjoining each other or in close proximity). This eliminates to a considerable degree the effect of the fertility slope. No cognizance is taken of the fertility slope by the Probable Error of the Mean Method. By working with differences between adjoining pairs of plots it becomes unnecessary to introduce the corrections for correlation between the yields of the respective plots of the two treatments (Student's Method). Without this correction for correlation, the odds by the "P. E. of the mean" method may be quite wrong if the correlation is large.

Imagine for example a series as follows:

	T. C. P. A.		T. C. P. A.
1A	100	2B	90
3A	85	4B	80
5A	60	6B	50
7A	50	8B	45
9A	40	10B	35

The fertility slope in the above figures has been exaggerated to make the point clear. The P. E. of the means would be very large due to the great variation in yield between the different plots of the series. As a result, the odds that the difference is significant would be low unless the correction for correlation between the two series is introduced into the calculation (which, of course, should be done to get the correct answer). It is easier, however, to work with the differences themselves as in Student's Method, thus escaping the necessity of these laborious coefficient of correlation calculations.

Discarding of Plots

If a plot is much higher or much lower than the other plots of the series it is natural to seek the cause. Sometimes the reason may be found rather readily. Errors in calculations of areas, mathematical calculations of weights, etc., poor stands of cane in the field, visible poor areas within a plot, proximity to a road or straight ditch, etc., may all bring about errors, which we may find by inspection. There are times, however, when we are unable to find the reason for the wide departure of a certain plot. Whether such plots should be retained or discarded is debatable. Perhaps our lack of knowledge as to the reason for a wide departure is not sufficient cause for including the widely departing plot in the series.

Several procedures have been suggested for dealing with aberrant plots.

Bond's Method

Bond's method (*Hawaiian Planters' Record*, October, 1930) has calculated a table of omissions which when applied to Ewa data indicated that on the average, one plot from each test departs so widely as to warrant omission.

"Twenty Per Cent of Mean" Method

Omission of departures greater than 20 per cent of the mean has also been suggested as a basis for discarding plots.

Chauvenet's Criterion

Y. Kutsunai has adapted Chauvenet's criterion of omissions for use with Student's Method. This criterion is based on the standard deviation of the series. The larger the standard deviation, i.e., the greater the natural variability of the series of plots under consideration, the larger the departures allowable. This seems more rational than the "twenty per cent of the mean" procedure, which takes no cognizance of the inherent uniformity or variability of the series.

The method has another advantage. It sometimes happens that a plot of series A and an adjoining plot of series B are both so low or so high as to be thrown out if considered separately, even though the *difference* between them is of the same order of magnitude as the other differences in the series. By dealing with the differences between plots of series A and the corresponding plots of series B, rather than with the individual plot yields, it is found that these plots do not diverge abnormally and should not be excluded.

Application of Student's Method

Several points in the application of Student's Method have caused differing opinions but after much discussion on the matter the following plan of attack appears best under the circumstances. No hard and fast rules may be laid down but when occasions permit the following procedure seems logical.

In a two-treatment test, A and B, it is deemed best to average the adjoining plots as follows:

1A 2B 3A 4B 5A 6B 7A 8B 9A 10B

1A	averaged	with	3A,	result	paired	with 2B
3A	"	"	5A,	"	"	" 4B
5A	"	"	7A,	"	"	" 6B
7A	"	"	9A,	"	"	" 8B

Plots 9A and 10B cannot be compared as the weight given 9A will cause an unequal value for this plot in the average figure. In a three-treatment test, A-B-C, no averaging should be made as all comparisons are aligned regularly and adjoining, thus:

1A 2B 3C 4A 5B 6C 7A 8B 9C 10A

1A	compared	with	2B
4A	"	"	5B
7A	"	"	8B

2B	compared	with	3C
5B	"	"	6C
8B	"	"	9C
4A	"	"	3C
7A	"	"	6C
10A	"	"	9C

In a four-treatment test, A-B-C-D, comparisons of A and B, B and C, C and D, and A and D may be made as in the three-treatment test as all of these comparisons may be found to be directly adjoining: The A and C comparison (non-adjoining plots), a system simulating that of the two-treatment test, is advantageous:

1A 2B 3C 4D 5A 6B 7C 8D 9A 10B 11C 12D

1A	averaged	with	5A,	result	paired	with 3C
5A	"	"	9A,	"	"	" 7C

9A cannot be compared with 11C as the weight in the average of 9A will be excessive when averaged with the other A plots.

It will be found of great advantage to have in mind at the time of installation of a new experiment the method of analysis of the harvest data. Where Student's Method is to be used on the yields secured it is advantageous to include extra plots comparing A and C, previously referred to, as directly adjoining. This will eliminate any necessity of averaging non-adjoining plots.

In a variety test where checks are located on either side of each variety plot we may make the following comparisons:

1A 2B 3A 4C 5A 6B 7A 8C 9A 10B 11A 12C

A=Check
B=Variety No. 1
C= " " 2

1A	averaged	with	3A,	result	paired	with	2B
5A	"	"	7A,	"	"	"	6B
9A	"	"	11A,	"	"	"	10B
3A	"	"	5A,	"	"	"	4C
7A	"	"	9A,	"	"	"	8C
11A					"	"	12C

11A may be compared with 12C directly as the balance of the A plots will not be unduly upset when 11A is given full value.

It was thought best to base our odds on cane instead of sugar where the reliability of the juice sampling may be questioned and where no significant difference or trend is to be noted in the juice figures. Basing odds on sugar in such cases, it is felt, introduces an additional source of error into the calculations.

Special attention should be given the juice figures from amounts of nitrogen, time of nitrogen, and like experiments, as these figures are very often significantly

changed by the treatment, and sugar should be the controlling factor. It was agreed to run odds for variety tests on sugar whenever possible.

Application of Student's Method to Actual Yield Data

Let us make a few comparisons of averages secured by Student's pairings and general averages as regularly used. The following actual examples will serve as illustrations:

EXPERIMENT 34 AN. H. C. & S. CO.
General Averages

N. Lbs.	T.C./Ac.	Q.R.	T.S./Ac.	Difference
R 204	47.1	7.45	6.32	......
S 279	52.6	7.52	7.00	+0.68
T 354	56.0	7.53	7.44	+1.12

There appears to be a good consistent gain up to and including the maximum treatment.

STUDENT'S PAIRED PLOT AVERAGES

						Odds on Cane
R	204	45.6	7.45	6.12	......	454 to 1
S	279	52.2	7.52	7.03	+0.91	
R	204	44.5	7.45	5.97	......	212 to 1
T	354	51.8	7.53	6.88	+0.91	
S	279	53.0	7.52	7.05	......	2 to 1
T	354	53.8	7.53	7.14	+0.09	

Here we get an entirely different slant on the proper amount of nitrogen to apply. We find no additional gain for the 354-pound treatment over the 279-pound treatment as was found in the general averages. We may have assurance that the gain represented will be somewhere near the gain which may be expected again under similar conditions as the odds are large, denoting great probability that the figure is true. We also find that the gain of the 354-pound treatment over the 279-pound treatment is due entirely to chance as the odds show us that the plots do not produce consistent gains, favoring the higher treatment as the general averages lead us to expect.

EXPERIMENT 50 AP PIONEER MILL CO.
General Averages

	P_2O_5 Lbs.	T.C./Ac.	Q.R.	T.S./Ac.	Difference
R	100	84.3	7.0	12.04	......
S	200	85.9	7.0	12.27	+0.23
T	300	87.8	7.0	12.55	+0.51
U	400	81.6	6.9	11.82	—0.22

There appears to be a consistent gain for applications up to 300 pounds.

STUDENT'S AVERAGES

		P_2O_5 Lbs.	T.C./Ac.	Q.R.	T.S./Ac.	Difference	Odds
R	6	100	84.6	7.0	12.08	......	....
S	6	200	84.2	7.0	12.03	—0.04	2¾ to 1
S	6	200	87.0	7.0	12.42	......	....
T	6	300	87.0	7.0	12.43	+0.01	2 to 1
T	6	300	87.0	7.0	12.43	......	....
U	6	400	84.7	6.9	12.27	—0.16	1¾ to 1
R	9	100	84.1	7.0	12.02	......	....
T	9	300	86.9	7.0	12.42	+0.40	3 to 1

These results show us at a glance that we have no guarantee of response from phosphate applications. Needless to say this does not support the general averages.

Additional instances of this same character where general averages give erroneous information may be found if reference is made to Experiment 22AP, H. C. and S. Co and Experiment 71AK, Pioneer Mill Co. 1931 crop.

An example is presented to show another phase of the question:

EXPERIMENT 17 PK. PIONEER MILL CO. 1931 CROP

GENERAL AVERAGES

	T.C./Ac.	Q.R.	T.S./Ac.	Gain
N	44.9	6.44	6.98	......
NP	63.3	6.92	9.14	+2.16
NK	48.8	6.64	7.34	+0.36
NPK	66.8	6.83	9.77	+2.79

There appears to be a good gain from phosphate and a fair additional gain from potash.

	T.C./Ac.	Q.R.	T.S./Ac.	Gain	Odds in Sugar
N	44.9	6.44	6.98	......	......
NP	65.3	6.92	9.44	+2.42	1999 to 1
N	44.9	6.44	6.97	......	......
NK	47.7	6.64	7.19	+0.21	12 to 1
N	45.5	6.44	7.07	......	......
NPK	66.0	6.83	9.66	+2.56	102 to 1
NP	64.4	6.92	9.31	+1.49	22 to 1
NK	51.7	6.64	7.78	......	......
NP	66.3	6.92	9.58	......	......
NPK	65.5	6.83	9.59	+0.01	less than 1 to 1

Excellent gains are found for phosphoric acid supported by high odds. The gain for the potash addition to nitrogen is quite small, unsupported by good odds.

When the phosphate addition is compared with the phosphate and potash addition no gain is to be noted from potash. This is rather contrary to the general figures, which show a 0.63 T.S./Ac. gain for the potash comparing the NP and NPK averages.

In still other cases we may have a gain of one treatment over another in nearly every comparison, but if these gains are extremely variable from one comparison to another the odds will be low, yet a good sugar gain will be reported. We must naturally concede a gain to the treatment even in spite of the low odds. When graphed the results will show this plainly. Again, on the other extreme, a very small uneconomic but consistent gain may be found in the series of comparisons for one treatment over another such that the odds work out to be over 9999 to 1. This does not mean that we should increase the fertilization. The magnitude of the differences between comparisons must be considered as well.

As another case for illustration, let us take Experiment 49 AN at Pioneer Mill Company.

GENERAL AVERAGES

	N. Lbs.	T.C./Ac.	Q.R.	T.S./Ac.	Difference
D	150	70.5	6.8	10.37	......
E	200	77.1	6.8	11.34	+0.97
F	250	81.9	6.9	11.87	+1.50
G	300	86.3	6.9	12.51	+2.14

STUDENT'S METHOD GIVES

	N. Lbs.	T.C./Ac.	Q.R.	T.S./Ac.	Difference	Odds
D	150	71.6	6.8	10.53	......	....
E	200	78.1	6.8	11.49	+0.96	174
D	150	71.6	6.8	10.33	......	....
F	250	83.9	6.9	12.16	+1.83	1249
D	150	69.9	6.8	10.18	......	....
G	300	86.5	6.9	12.53	+2.35	1666
E	200	75.9	6.8	11.16	......	....
F	250	81.1	6.9	11.76	+0.60	7¼
F	250	81.5	6.9	11.81	......	....
G	300	86.3	6.9	12.51	+0.70	6¼

Differences appear quite similar to the general averages in the first three comparisons. In the last two the differences become more difficult to secure and the differences will be found to vary more and more. The low odds here are due entirely to plot variations. Such cases must be considered from all evidence at hand, averages, odds, graphs and common sense, as no guides can be made up to suit all cases. A degree of doubt is shown in this experiment, however, over the gains made by the two higher applications which are not indicated by the general averages.

These illustrations go to show that fallacies may be represented in general averages which are not apparent unless a careful analysis is made. It is not meant to

convey the impression that general averages in all cases differ radically from Student's averages, the trend in many cases is identical, but that differences often occur and we must have means for determining these errors.

Graphic Illustration of Plot Yields

It is quite possible to bring out graphically an accurate picture of the plot yields to show at a glance the difference in treatments qualitatively. It is difficult without representing the averages to judge the exact quantitative response, however. Averages are often transferred from the original sheets to find their way to summarization of the crop, various and sundry reports, and are often noted on maps of the repetition of the test. It is quite impossible to carry along the graph to depict the quality or reliability of the response in these cases. A single figure denoting the measure of reliability as odds is quite superior in this respect.

Where no measure of the reliability of the average differences is attached to the write-up and the averages have been transferred and retransferred the reliability of the results is invariably forgotten. A large gain or loss may be represented and this is taken at its face value, producing as a result an extremely erroneous impression or even a costly mistake.

It is not intended to create the impression that graphs should be omitted from the original experimental write-up, but it is felt that their value is limited and cannot fully fill the place of the reliabihty figure—odds.

Manganese as an Essential Element in the Growth of Sugar Cane

By L. E. Davis

Prior to the beginning of the present century ten elements were generally considered essential for the growth of plants. These elements are: carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, calcium, magnesium and iron. As a result of recent investigations there is now considerable evidence to indicate that this list should be extended. Although the subject is still quite controversial, many conservative students of plant nutrition seem inclined to favor the view that two or more other elements besides those listed above are probably essential to at least some plant species (1).

Manganese, copper, boron, zinc, and other elements are considered by many investigators to be capable of stimulating plant growth when available in minute quantities (1, 2, 3). Many of these elements are undoubtedly toxic to most plants when present in concentrations exceeding a few parts per million of the nutrient solution (4, 5).

A substance may conceivably stimulate certain functions of plants or animals under proper conditions, and still not be absolutely indispensable. This is true of a large number of organic and inorganic compounds as can be seen from a casual glance through the *United States Dispensatory*.

Persistent effort has been made to answer the question "Is manganese (and/or copper, etc.) indispensable to plant growth?" (6, 7, 8.) Obviously to answer this question finally, four conditions are necessary:

(a) Plants must be grown both with traces of the element in question present in the root zone and in an environment free from the element.

(b) A sufficient number of widely different species must be studied to establish a reasonable presumption that the individual conclusions have general application. Obviously all species and their varieties cannot be examined. In this sense we cannot rigorously prove that even potassium or calcium are universally essential.

(c) The experiments should be conducted under varied conditions to exclude the possibility that the element, while essential under one condition, may not be indispensable under all conditions. Again, our assurance is limited by our inability to carry out an indefinite number of experiments.

(d) The possibility that other elements can be successfully substituted for the one being studied must be eliminated.

Manganese probably has been studied more carefully and by a larger group of workers than most of the elements formerly considered non-essential. The careful work of Oswald Schreiner, W. E. Brenchly, J. S. McHargue, G. Bertrand, F. T. McLean, G. Samuel, C. S. Piper, O. C. Bryan and others has demonstrated that species as diverse as tomatoes and sugar cane require traces of manganese (8, 9, 10, 11, 12, 13, 14, 15).

When plants are grown in culture media very carefully freed from manganese but containing sufficient quantities of elements known to be essential and with traces of others such as boron and zinc, a chlorosis of the leaves appears in a few weeks, even with quite large amounts of iron present. This chlorosis is often characterized by an alternation of yellow-white tissue with green tissue. In the tomato and tobacco the etiolated areas appear as spots; in sugar cane and maize they form stripes (8, 9, 10). The leaves may then begin to wither and become twisted. Splitting along the chlorotic streaks or stripes then occurs in severe cases followed by reddening of the tissues and death of the leaves. The plant becomes stunted and may eventually die after a short period, although new leaves, free from chlorosis may temporarily appear, only to wither and die.

In sugar cane these symptoms are characteristic of a disease commonly known in Hawaii as Pahala blight (10). In the field this disease has been successfully controlled by McGeorge, who made large applications of sulphur to the soil. W. W. G. Moir and Raymond Conant recently have removed the symptoms of this disease with applications of manganese compounds either to the leaves or to the soil. Similar results were obtained by Atherton Lee, J. C. Thompson and Royden Bryan (10).

Quite frequently the disease appears very early in young cane but disappears later in the season. Only in very severe cases does it result in a complete stunting of the cane, followed by death.

Following his local studies of this disease, Lee collaborated with J. S. McHargue, of Kentucky Agricultural Experiment Station, who is a pioneer in work with manganese. McHargue had observed chlorotic symptoms in oats and wheat which resembled the chlorosis found in Pahala blight of sugar cane, when those cereal plants were grown without manganese.

McHargue grew cuttings of Yellow Caledonia in sand cultures, some of which contained small amounts of manganese and others of which were free from that element.

The cuttings grown with manganese-free solutions showed very definite chlorotic stripes while those with manganese present were normal. This work is described by Lee and McHargue in the reference cited herewith (10).

During the spring of 1928, G. R. Stewart, then chemist of this Experiment Station, inaugurated a series of water culture studies with the object of determining the requirement of sugar cane for various elements such as manganese, silicon, fluorine, iodine, bromine, zinc, boron, copper and titanium.

Some very carefully repurified chemical nutrients were prepared by Fred Hansson. C. P. chemicals were repeatedly crystallized until they were free from the elements to be used in the experiments. A very large proportion of the success realized in the experiment discussed below must be ascribed to the careful purification of the chemicals used. All recent investigators have emphasized the necessity of using chemicals very carefully purified to exclude manganese. The presence of traces of this element in the supposedly manganese-free cultures may cause negative results although occasionally very small amounts may be insufficient to favor normal growth (8).

The cultural studies described in the following paragraphs were assigned to the author, who carried out the experiments under the supervision of Mr. Stewart.

Seed pieces of H 109 cane, a variety not extremely susceptible to Pahala blight, were obtained from Waipio substation through the courtesy of J. A. Verret. These seed pieces were planted in silica sand which had been digested with hydrochloric acid and repeatedly washed with distilled water. Following a technique devised by McGeorge, the young shoots were excised with some care, in order to eliminate as much seed piece tissue as possible. Thus the amount of residual manganese which might be derived from the parent cane was brought to a minimum.

The cane shoots were immediately transferred to pyrex glass flasks capped with small wood covers coated with a clear lacquer free from soluble substances.

The basic nutrient solution was prepared from doubly distilled water condensed in block tin and collected in pyrex glass receivers. The composition of the culture solution was very nearly that used by Sommer in California in her work on boron and zinc; the potassium nitrate was reduced somewhat (6).

	Parts per Million
Potassium nitrate, KNO_3	575
Monopotassium phosphate, KH_2PO_4	150
Magnesium sulphate, $MgSO_47H_2O$	500
Sodium chloride, NaCl	12.7
Aluminum sulphate, $Al_2(SO_4)_3$ 18 H_2O	6.2
Iron tartrate, Mn free	5.0
Calcium sulphate, $CaSO_4$, 300 cc. saturated solution per liter of nutrient	....

The reaction of this solution was about 5.8 pH.

The following elements were also added to certain of the cultures:

	Parts per Million
Iodine (as potassium iodide) I=	0.5
Fluorine (as sodium fluoride) F=	0.5

Silicon as small amounts of dialyzed silica.

These elements were distributed in such a way among both the manganese-free cultures and the controls that various combinations were possible. There were three sets of four plants each receiving no manganese or twelve in all, and five sets of four plants each receiving manganese at a concentration of 0.5 part per million. Two of the latter were accidentally injured while changing the nutrient solutions, leaving eighteen control plants. The culture solution was completely changed about every four days and was also brought up to a uniform volume daily.

During the first two weeks all plants became slightly chlorotic. The entire leaf surface of a number of leaves was a rather pale green, but there was no striping. The controls, containing manganese, were slightly more chlorotic than the manganese-free cultures. Excess iron tartrate was immediately added. Within a day or two all the plants assumed a normal, lustrous green color. The iron ration was then maintained at 20 parts per million of iron tartrate (about 5

parts per million of iron), which was sufficient to maintain the controls in a healthy green condition throughout the experiment.

In less than four weeks a number of the plants which were not receiving manganese showed a tendency toward a chlorotic striping of the leaves. In seven weeks this chlorosis had become severe on all the leaves of all the plants that were grown without manganese. At no time subsequent to the addition of excess iron mentioned above was there any appearance of the uniform etiolation which is usually considered characteristic of iron-deficiency chlorosis.

At the end of three months, an attempt was made to restore six of the manganese-free plants by supplying them regularly with the same solution as the controls, i.e., a solution containing 0.5 part per million of manganese.

In the manganese-free cultures the affected leaves began to wither and became severely twisted and intertwined. This condition was followed by splitting along the chlorotic stripes and by the appearance of reddish spots which later became reddish-brown streaks. All of these earlier leaves withered and finally died.

In five months when growth had apparently ceased for some time, new green leaves began to appear. These leaves did not become chlorotic but rapidly (i.e., within a week or two) withered. In all cases the entire plant was now in a very poor condition and three of the six began to die; one was apparently already dead at the end of six months. At this time the whole experiment was harvested.

Five of the chlorotic plants to which manganese had been added began to put out new green leaves within a month of the first addition. These leaves grew normally but rather slowly. The sixth plant did not appear to have sufficient vitality to recover although some new leaves appeared.

All of the control plants were apparently healthy, quite green, and still growing slowly at the time of harvest, although they were root-bound in the rather small containers.

Roots, stems, leaves, tops, and trash of all plants were collected, carefully dried, and weighed. A tabulation of individual dry weights of the combined tissues of each plant is to be found in the table below. Roots, tops with leaves, and stalks were separately weighed. Each of the separate parts of every manganese-free plant was proportionately smaller in weight than the corresponding tissues of the control plots; therefore, to avoid presentation of superfluous data, only the total plant weights are given here.

DRY WEIGHTS OF EACH PLANT IN GRAMS

Manganese-free plants		Controls	
No. 3	14.1	No. 5	39.2
4	17.4	6	38.9
11	19.1	7	49.9
12	16.8	8	39.2
23	8.8	13	33.2
24	9.3	14	27.0
Average	14.3	15	44.3
		16	24.5
Manganese added after 3 months		17	60.8
		19	20.4
No. 1	38.3	20	26.8
2	27.2	25	41.9
9	31.1	27	43.4
10	14.1	28	36.0
21*	10.8	29	18.5
22	21.0	30	35.6
Average	23.8	31	37.5
		32	41.5
		Average	36.6

* This plant did not recover.

The control plants weighed on the average 22.3 grams more than those receiving no manganese, or showed 2.5 times as much growth, and weighed 12.5 grams more than those receiving manganese during the last three months, or showed 1.5 times as much growth. These results were found to be highly significant by a mathematical analysis. The method was obtained from Fisher's *Statistical Methods for Research Workers.*

The plants receiving manganese for three months weighed 9.5 grams more than those receiving no manganese or 1.6 times the growth. This difference was mathematically of doubtful significance. The odds were low (about 20 to 1) because one of the plants failed to recover and consequently the distribution was less uniform than if all six had shown approximately equal improvement.

The experiment was followed by others in which an iron salt containing small amounts of manganese as an impurity was used in all cases. In no instance was there any appearance of chlorosis of any type. The objective of four of these experiments was to determine whether any of the following elements was essential: boron, copper, iodine, fluorine, bromine and zinc. Evidence was obtained indicating that copper and boron were stimulating but it was not proved that they were essential. Indeed the fact that the controls grew normally in the first experiment, although no copper or boron were added, would suggest that copper and boron are possibly not essential. However, no special effort was made to be absolutely certain that copper or boron were absent as impurities. Recent work by Sommer, who very carefully eliminated all traces of copper and boron from

her solutions, indicates that copper and boron are essential, even in the presence of manganese, for certain plants (7).

In a sixth experiment increasing amounts of manganese were used in addition to that present as an impurity (i.e., about 0.2 part per million). The amounts added were: 1.5, 3, 4.5 and 6 parts per million. Five parts per million of iron were used in all cases. All the plants grew fairly well, although the variety used was Lahaina. The best growth was observed with 4.5 and 6 parts per million of manganese. The differences were 11.9 grams and 11.6 grams more weight respectively than those receiving manganese as an impurity only. The plants were paired by choosing for excision and transplanting five cuttings (one for each experiment) at intervals of about 4 days. The odds by Student's method were about 200 to 1.

These experiments confirm the results achieved by Lee and McHargue (10). A disorder having the symptoms of Pahala blight occurs in sugar cane grown in cultures free from manganese. In the field Pahala blight can be remedied by applications of manganese compounds. It is reasonable to conclude that the disorder experimentally induced by McHargue and by the author is identical with Pahala blight, and that Pahala blight is a physiological disease due to deficiency of manganese. The results obtained by the author appear to go further in that they show that sugar cane cannot survive in water cultures without manganese, and that given a sufficient supply of other nutrients, a moderately large concentration of manganese is not toxic to sugar cane but is actually stimulating.

To return to the four conditions discussed earlier in this paper:

1. It is apparent that a manganese-deficiency disease of sugar cane can be achieved with certainty only where the solutions are very carefully freed from manganese. In this connection it must be remembered that the plants used all had opportunity to derive a small amount of manganese from the parent cane. However, under certain conditions the amounts of manganese available from the soil solution in the field appear to be insufficient, and applications of manganese can be recommended.

2. The author has contributed results applicable only to *Saccharum officinarum*, var. H 109. Nevertheless the results of McHargue with Yellow Caledonia (10) and with oats and wheat (15) and results achieved by others with oats, tomatoes, corn and tobacco (4, 8, 9, 11, 12, 13, 14) indicate that manganese may be essential to many varieties of plants.

3. Experiments connecting chlorosis with manganese deficiency have been carried out in water cultures, sand cultures, soil pots and in the field in a variety of soils and climatic conditions.

4. The question still remains: Can other elements be substituted for manganese? This is still an open question. No experimental results with sugar cane are known to the author which definitely exclude the possibility that other elements may produce the same effects as manganese. O. C. Bryan found that manganese and copper both appeared to control a chlorosis of cowpeas, beans, and sorghum grown in the raw peat soils of the Florida Everglades, but that the best results were achieved with both copper and manganese present (18). G. Samuel and C. S. Piper have recently demonstrated, however, that neither boron,

aluminum, zinc, copper, cobalt, nickel, barium, silicon, or iodine could replace manganese in tomatoes and in various grasses grown in carefully purified culture media (8).

Several theories have been advanced to explain the action of manganese. Apparently none of these rest upon adequate experimental evidence (11, 13, 20). It is assumed by several writers that manganese acts as a catalyst, that in some way it activates processes in the plant which control the formation of chlorophyl. It is possible that manganese acts as an oxidizing-activator for iron. Sideris has recently suggested that there is most probably some such relationship between titanium and iron. It must be remembered that such terms as catalyst, activator, etc., are inevitably vague since they cover a lack of precise knowledge.

The conclusion tentatively reached is that manganese by some mechanism at present unknown, aids in the normal formation of green tissue, and that in the complete absence of manganese sugar cane cannot be grown normally and in fact fails to survive after a period of a few months.

The following cited literature represents but a small proportion of the growing literature available upon this subject, and upon the stimulating effect and indispensability of other elements.

Summary

In the past ten elements have been considered essential to plant growth. Probably other elements, in particular manganese, should be considered indispensable. A chlorotic disorder similar in its symptoms to Pahala blight of sugar cane has been found in several species of plants to be associated with a deficiency of manganese. More specifically, Lee and McHargue found that the symptoms could be induced in sugar cane grown in water cultures from which manganese was carefully excluded. The author has succeeded in confirming this result and in demonstrating further that the condition proceeds from bad to worse and finally ends in death of the plant. He has also shown that manganese is stimulating to sugar cane in relatively large concentrations, provided other nutrients are present in sufficient amounts. It is concluded tentatively that manganese is essential to sugar cane.

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A Rapid Method for the Determination of Potash

By Paul L. Gow

Introduction

During the last two years we have come to feel very keenly the need for rapid and sensitive analytical methods which are capable of as high, or in some cases higher, degrees of accuracy as are the standard methods heretofore applied to soils, soil extracts, percolates and irrigation water.

A number of factors more or less peculiar to the work in which this laboratory has been engaged have contributed to this demand. Some of these factors are: (a) the necessity of rapidly handling a great many routine analyses for the purpose of regulating fertilization; (b) the necessity of making large numbers of analyses in connection with special researches which require the determination of only one or two substances instead of the usual more complete analyses; (c) the desirability of making surveys of soils, irrigation waters, etc., with respect to only one or two of their constituents; (d) the necessity for increased accuracy for certain special problems; and (e) the chemical peculiarities of the types of samples with which we have to deal.

In particular, soils and soil extracts offer materials for analysis which are chemically very complex and which therefore entail many vexing analytical problems. In applying the ordinary analytical methods to such materials the time and effort involved in analysis are increased while the accuracy and reliability of the methods are decreased. Many Hawaiian soils, moreover, possess comparatively large amounts of extractable titanium and manganese and appreciable quantities of vanadium and other minerals which tend to interfere wi'h analytical procedure and intensify the difficulties and inaccuracies inherent in soil analyses.

Especially was it desirable to secure a new method for the determination of potash in materials where the amounts of potash present are usually very small. The Lindo-Gladding gravimetric method heretofore used is much too slow and tedious to allow of its use in many investigations involving analysis of a large quantity of samples, especially if the determination of only potash or potash and phosphate is desired. Moreover, it seems impossible to secure by means of this method, when applied to the materials with which we have to deal, the degree of accuracy which we desire for much of our work without employing refinements of procedure which would render the method so slow and unwieldy as to prohibit its use.

A number of methods for potash determination were investigated and found unsatisfactory, including the Hill (1) colorimetric method as outlined by Yoe (2) in his book on photochemical analysis. However, after rather extensive experimentation certain modifications of the method were developed which made it admirably applicable to much of our work. By this modified Hill method we found that samples can be analyzed in a quarter or less of the time required by

the Lindo-Gladding method, and that less of the analyst's time and attention and considerably smaller quantities of reagents and apparatus are required. With soil extracts and waters our modification of this method enables the analyst to obtain a higher degree of accuracy than does the standard method. The chief limitation on the new method is that it cannot give as high a degree of accuracy as can the gravimetric method with materials containing relatively large quantities of potash such as cane stalks and leaves, crusher juices and fertilizers. The accuracy of the method is strictly limited by the degree of accuracy with which intensities of color may be compared. This is such as to allow determinations to be made to three significant figures, while with materials containing more than 1 per cent K_2O it is usually desirable to make determinations to four significant figures. However, it is precisely with this class of analyses that the gravimetric method is not open to the serious objections which we found to apply in the case of soil extracts, soil percolates and irrigation waters.

Description and Theory of the Colorimetric Method

This method consists essentially of precipitating potassium chloroplatinate (K_2PtCl_6) by means of its insolubility in alcohol, dissolving the precipitate in water and developing a color by the addition of stannous chloride ($SnCl_2$). The intensity of the yellow color thus produced is directly proportional to the amount of platinum present in the precipitate and hence to the amount of potash present.

The gravimetric method requires the removal of organic matter, silica, iron and alumina, calcium and ammonium salts before the precipitation of the potassium chloroplatinate; but the colorimetric method requires the removal only of organic matter, ammonium salts and silica, if it is present in much quantity. Moreover, the gravimetric method depends upon the weight of the precipitated salt while the colorimetric method depends only on the amount of platinum present in the precipitate. Impurities which would give rise to errors in the gravimetric method have no effect on the colorimetric method, the only impurities affecting the latter method being platinum or some colored substance not reducible by stannous chloride, both of which are very easy to guard against.

Nowhere in the literature dealing with this method is there any mention of the reaction to which this color is due. However, Friend (3) states that chloroplatinic acid (H_2PtCl_6) is reduced to chloroplatinous acid (H_2PtCl_4) by sulphur dioxide in aqueous solutions, changing the color of the solution from yellow to deep red. We have found that the color produced by stannous chloride in strong solutions of platinic chloride is a deep red, which becomes orange and then yellow on dilution. Hence, the reaction to which the color is due is probably:

$$H_2PtCl_6 + SnCl_2 = H_2PtCl_4 + SnCl_4.$$

Analytical Procedure

A sample should be chosen, where possible, of such size as to contain between 1.0 and 10.0 mg. of K_2O. In the case of a soil extract or water in which K_2O alone is to be determined, the sample, usually 100 ml., should be evaporated in a

porcelain dish to dryness and then carefully ignited. The muffle should be at low red heat and the sample left in just long enough to destroy the organic matter and drive off any ammonium salts which may be present. The residue is then taken up in 20 to 30 c.c. of dilute hydrochloric acid and heated for a few minutes on the steam bath. If silica appears in appreciable quantities, or if much carbon has been left from the ignition the sample should be filtered into another porcelain dish.

If the sample is an extract which is to be analyzed for other substances besides potash, the ordinary procedure for such analysis may be followed until silica has been separated. The filtrate and washings from the filtration of silica should be caught in a 100 ml. volumetric flask, the volume made up to the mark, and 25 ml. taken for potash determination and placed in a porcelain evaporating dish.

Platinum chloride solution is then added, 1 to 3 c.c. of 2 per cent solution usually being sufficient.

The sample is evaporated to dryness on the steam bath. (It is best to allow the residue to become completely dry. It will not hurt even if it bakes on the steam bath for some time.) The dish is then cooled and the residue taken up in 20 to 30 c.c. of 92 to 95 per cent ethyl alcohol. The residue must be thoroughly broken up with a policeman to enable solution of all soluble material. The alcohol is then decanted into a Gooch crucible to which suction is being applied. The residue should now be thoroughly ground up with the policeman and washed into the crucible by means of a stream of alcohol. Four washings under suction with small portions of alcohol will be sufficient to remove all excess platinum chloride. The crucible is then dried for a few minutes at about 100° C. to remove the alcohol.

The crucible is now placed upright in a funnel and the K_2PtCl_6 is washed through with hot water acidified with a HCl. The washings are caught in a 250 ml. volumetric flask (a 100 ml. flask if the quantity of K_2PtCl_6 is very small). After cooling the volume is made up to the mark and an aliquot is pipetted off into a 100 ml. volumetric flask. Fifteen to 20 c.c. of concentrated hydrochloric acid and 5 c.c. of stannous chloride solution are then added. The color develops immediately. The volume of the solution is then made up to 100 ml. and the color is compared with that of a standard solution by means of a colorimeter.

The choice of the proper aliquot for the development of the color is the most difficult part of the analysis. The amount of precipitated K_2PtCl_6 may serve as a guide to an experienced worker, but the appearance of this precipitate is often misleading as to the quantity of K_2PtCl_6 contained therein. For accurate work the intensity of the color of the solution to be compared should not be more than twice nor less than half that of the color of the standard. For samples containing more than 4 mg. of K_2O the solution of K_2PtCl_6 when made up to 250 m. volume will have a yellow color due to the K_2PtCl_6. This color may be used to indicate the necessary dilution by roughly comparing with a set of permanent preliminary standards made up by dissolving various amounts of K_2PtCl_6 in water acidified with HCl and kept in 250 ml. volumetric flasks. For concentration of K_2O less than 4 mg. in 250 ml. it may be necessary to make two attempts at securing the proper dilution before the color developed is within the range of the standard. It is well to err on the side of too little dilution when the necessary dilution is not known. If the solution proves to be too concentrated after the development of the

color it may be diluted again by merely adding water and the proper quantities of stannous chloride and hydrochloric acid. We have found that this procedure does not introduce any error. It is often convenient to prepare two standards, one containing 0.004 mg. K_2O per ml. and the other containing 0.002 mg. per ml.

The standard solution is made by weighing out 0.3166 g. KCl or 0.3700 g. K_2SO_4, dissolving in water and hydrochloric acid and precipitating as usual with platinum chloride. The precipitated K_2PtCl_6 is dissolved in hot water, 40 to 50 c.c. of concentrated hydrochloric acid is added and the solution is made up to 500 ml. One hundred ml. of this solution is used to make one liter of standard which contains 0.04 mg. K_2O per ml. When this standard is to be used, 10 ml. is taken together with 20 c.c. of concentrated hydrochloric acid and 5 c.c. of stannous chloride solution and the volume is made up to 100 ml. This solution contains 0.004 mg. of K_2O per ml. The color standard should not be made up until it is needed. If properly acidified to prevent hydrolysis, the standard K_2PtCl_6 solution will keep indefinitely.

The stannous chloride solution is made by dissolving in concentrated hydrochloric acid as much metallic tin as it will dissolve. The solution is kept with a few pieces of tin in contact with it and should be protected from the air as much as possible. It is best to keep it in an aspirator bottle with a layer of mineral oil over the top of the solution.

Experimental Investigation

The following tables give the results of investigations undertaken to determine the accuracy of the colorimetric method:

TABLE I

A set of 10 samples were analyzed by the usual gravimetric method. After weighing, the K_2PtCl_6 was dissolved from the crucibles and determined colorimetrically to determine if the color was, in fact, strictly proportional to the amount of K_2PtCl_6 present.

Per Cent K_2O Colorimetric	Per Cent K_2O Gravimetric
0.021	0.022
.025	.024
.033	.039
.020	.021
.030	.035
.041	.041
.021	.021
.032	.033
.036	.036
.024	.033

TABLE II

Samples were analyzed both colorimetrically and gravimetrically. In the case of these samples the colorimetric determinations were entirely separate from the gravimetric determinations.

Colorimetric Method	Gravimetric Method	
0.021	0.022	Citric acid extracts
0.019	0.019	Numbers represent Per
0.020	0.023	Cent K_2O
32	32	
31	36	Irrigation waters
33	36	Numbers represent
32	36	p. p. m. K_2O
32	36	

TABLE III

Duplicate samples were analyzed colorimetrically to determine if the method is capable of checking itself over a wide range of concentrations.

Citric Acid Extracts Per Cent K_2O	Water Extracts p. p. m. K_2O	Water Solutions of KCl p. p. m. K_2O
0.019	10.2	204
0.018	10.0	204
0.021		
0.018	13.7	194
	14.0	192
0.022		
0.022	17.8	52.8
0.023	18.2	52.4
0.020	32.0	40.4
0.021	32.0	41.2
0.027	83.2	212
0.027	81.2	206
0.028	156	206
0.028	156	208
	4.4	
	4.4	
	25.2	
	24.[illegible]	
	53.2	
	52.8	
	120	
	118	
	190	
	192	

These results may be taken as indication of the accuracy obtainable by this method. When carefully applied results may be secured which are reasonably correct to three significant figures. The accuracy is limited by the accuracy with which colors may be compared in the colorimeter. For such small quantities this is as great accuracy as can be expected from any method.

TABLE IV

A set of colorimetric determinations was made on 100 ml. portions of the same citric acid extract to which varying quantities of K_2O had been added.

Mg. K_2O Added	Theoretical Per Cent K_2O	Per Cent K_2O Found
0	....	0.022
0	....	.022
0	....	.023
2	0.042	.041
4	.062	.064
6	.082	.084
8	.102	.102
10	.122	.121
12	.142	.140
14	.162	.162
16	.182	.172
18	.202	.202

TABLE V

An investigation was undertaken to determine the optimum amounts of stannous chloride solution and hydrochloric acid to be used in developing the color, and to determine whether the intensity of the color was at all dependent upon the amounts of the reagents used. In this table the ratios given are the ratios of the intensity of the solution under investigation to that of a standard solution containing 0.2 mg. K_2O as K_2PtCl_6; 5 c.c. of stannous chloride solution and 25 c.c. of concentrated hydrochloric acid in 100 ml. of solution. The solutions whose colors were to be compared all contained 0.2 mg. K_2O with varying amounts of stannous chloride and hydrochloric acid. If the intensity of the color is dependent only on the amount of K_2PtCl_6 in solution the ratios should all be 1.00. The ratios were checked by reading with the colorimeter cups set at three different heights.

		Ratio		
c.c. HCl per 100 ml.	c.c. $SnCl_2$ per 100 ml.	90 mm.	75 mm.	60 mm.
25	1	1.01	1.00	1.00
25	3	1.01	1.00	1.02
25	10	1.01	1.00	1.02
25	15	1.01	1.01	1.02
25	20	1.03	1.00	1.00*
25	25	1.02	1.01	1.05*
25	30	1.06	1.05	1.05*
25	40	1.07	1.07	1.07*
25	50	1.03	1.04	1.07*
0	5	Impossible to match tints		
10	5	1.00	1.00	1.02
35	5	1.01	1.01	1.00
50	5	1.06	1.08	1.05*
75	5	Impossible to match tints		

The samples marked with an asterisk were of different tint than the standard, in each case the tint of the samples being redder. It is evident that the intensity of the color is not dependent upon the amounts of stannous chloride or hydrochloric acid used within wide limits and that a wide range of amounts of these two reagents may be used in developing the color.

Discussion

It was necessary to make certain modifications of Hill's method before it could be applied to soil extracts and waters. Hill advised adding concentrated sulphuric acid to the sample before evaporating and igniting in order to convert all of the potash present to the sulphate. This was done to decrease the possibility of loss of potash due to volatilization during ignition, the sulphate being less volatile than many other salts of potash likely to be present. However, this procedure also converts the salts of other metals present to sulphates, and it was found that upon precipitating the potassium chloroplatinate and taking up the residue with alcohol a very heavy residue of sulphates insoluble in alcohol was left. It is impossible to wash all of the excess platinum chloride out of this residue and such procedure always leads to very high results, often to errors of 200 and 300 per cent. However, magnesium, ferric, manganous and calcium chlorides are all fairly soluble in alcohol and are readily dissolved by the quantity of alcohol used to take up the residue. The solubility of sodium chloride in 95 per cent alcohol at 28° C. is 0.4 gram per 100 grams of solution, so up to 0.2 gram of sodium chloride will be dissolved. This is 30 to 150 times the amount of potassium chloride present in the sample. In practice we have found that if the bases present are converted to chlorides, practically all of the residue except the K_2PtCl_6 goes into solution and that the excess platinum chloride is readily washed out. It is necessary, however, to carry out the ignition of the sample at as low a temperature and for as short a time as possible to avoid losses due to volatilization of potassium salts.

A second modification of the original Hill method was necessary in the matter of the development of the color. According to Hill all that is necessary to develop the color is to add 3 c.c. of stannous chloride solution to the water solution of K_2PtCl_6. We found that this leads to a wide range of tints and that often samples prepared in this way cannot be compared at all with the standard. However, the addition of a fairly large quantity of concentrated hydrochloric acid prevents cloudiness due to hydrolysis of the platinum salt and gives the same tint with all samples.

It seems probable that the increased accuracy of the modified Hill method over the Lindo-Gladding method is due to the fact that the residue of potassium chloroplatinate and other salts left after precipitation is much smaller in the case of the Hill method, allowing less opportunity for mechanical retention of platinum chloride. Moreover, the crystals of K_2PtCl_6 produced by the Hill method are very fine, due to the small amounts of potash present, while those produced by the Lindo-Gladding method are often quite coarse. Vürtheim (4) mentions that mother liquor containing platinum chloride may be occluded in large crystals of potassium chloroplatinate precipitated from strong solutions. Also, any impurity present in the residue on precipitation which is not dissolved by the alcohol or the ammonium chloride wash used in the Lindo-Gladding method will be weighed and cause high results, while impurities present in the Hill method, unless they be colored substances not reducible by stannous chloride (which type of substances do not normally occur in soils and waters) do not give rise to any error. It will be noted that all of these sources of error tend to give high results and that in

Tables I and II where colorimetric results are compared with gravimetric results, the latter are higher wherever the two methods fail to check.

It is desirable that the amount of K_2O in the sample taken for analysis be kept small. If the amount of K_2O is between 1 and 10 mg. the precipitate of K_2PtCl_6 will consist of very fine crystals which will offer little opportunity for mechanical retention or occlusion of platinum chloride. If a soil contains between 0.01 per cent and 0.10 per cent extractable K_2O a 100 ml. portion of extract is suitable. Otherwise, if possible, the amount of extract taken for analysis should be regulated so as to bring the amount of K_2O in the sample within these limits. However, most of the soils with which we have to deal contain amounts of extractable K_2O lying between 0.01 per cent and 0.10 per cent.

According to Seidell (5) the solubility of K_2PtCl_6 in 94.7 per cent alcohol at 14° C. is 20 mg. per liter. Data for the temperature at which we work were not available; but the solubility at 25° C. to 30° C. would not be much greater. A sample containing 1.0 mg. of K_2O will give a precipitate of K_2PtCl_6 weighing 5.16 grams. If 50 c.c. of alcohol is used to take up the residue and wash and the solubility given by Seidell is assumed, 0.1 mg. of K_2PtCl_6 will be dissolved providing equilibrium is established. This would cause an error of 20 per cent. However, the rate of solution of K_2PtCl_6 in alcohol is very slow, so that if the K_2PtCl_6 is already crystallized out before the alcohol is added and washing be carried out under suction with small portions of alcohol, the error due to the dissolving action of the alcohol will be very small. The solubility of this salt increases rapidly as the concentration of the alcohol decreases, being 200 mg. per liter for 58.5 per cent alcohol. Therefore the alcohol used should be between 92 and 95 per cent. We have found in practice that using alcohol of this strength and following the procedure outlined no appreciable error is produced due to dissolving of K_2PtCl_6.

Summary

With some modification, the Hill method of colorimetric analysis for potash is suited to the analysis of soil extracts, soil percolates and irrigation waters.

This method has the following advantages over the Lindo-Gladding method for this type of analysis:

1. Requires less than one-fourth as much time for analysis.
2. Requires less of the analyst's time and attention.
3. Requires a smaller quantity of reagents and apparatus.
4. Gives greater accuracy without employing special refinements of procedure.

The method, when carefully applied, is capable of yielding results which are reasonably correct in the third significant figure, which seems to be the limit of accuracy permitted by colorimetric methods.

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Determination of the Ripeness of Cane by Means of Pre-Harvest Sampling

By Wm. Wolters

Scope

The ripening of cane fields is controlled in part through correct regulation of cultural practices such as time of fertilizer application, amounts and kinds of fertilizers, and irrigation, in relation to the development of the cane plant, and the time of year that the fields are to be harvested. Through these measures the plant is helped to reach its maximum ripeness, especially through the difficult ripening months of the winter season. After the month of March the cane plant usually begins to ripen of its own accord. Climatic influences are the most significant factor over which we have no control.

Pre-harvest sampling, conducted on a systematic basis, is valuable not only as a guide to the sequence in which fields are to be harvested, but also in determining the effects of cultural practices, fertilization, irrigation and weather on the ripening of cane.

Value of Pre-Harvest Sampling

Through study and experience, a technique of sampling cane in the field has been developed to meet our conditions and it has been used with success as shown by the following data.

To illustrate: Thirty-nine out of 41 fields were sampled at periodic intervals in 1929. It was impossible to sample 2 fields correctly. Table I shows the average figures for the pre-harvest and field harvested samples (actual data).

TABLE I—1929 CROP

Samples	Brix	Pol'n	Purity	Cane Ratio	Per Cent Juice P_2O_5	Per Cent Juice K_2O
Pre-harvest	18.69	16.83	89.09	7.39	.025	.128
Actual	18.56	16.25	87.55	7.74	.027	.143

Our sampling technique was improved upon for the 1930 crop and the results are shown in Table II. Thirty-seven out of 42 fields were sampled. It was impractical to sample the remaining 5 fields. The omission of certain fields from a sampling schedule is explained in later paragraphs.

TABLE II—1930 CROP

Samples	Brix	Pol'n	Purity	Cane Ratio	Per Cent Juice P_2O_5	Per Cent Juice K_2O
Pre-harvest	18.25	16.14	88.44	7.74	.027	.099
Actual	18.19	16.09	88.40	7.74	.026	.110

Table III shows the results for the 1931 crop. It was possible to sample correctly all the fields (39) but the results were not in such close agreement as those of the 1930 crop due to more D 1135 cane being harvested in 1931 than in 1930.

TABLE III—1931 CROP

Samples	Brix	Pol'n	Purity	Cane Ratio	Per Cent Juice P_2O_5	Per Cent Juice K_2O
Pre-harvest	18.80	16.49	87.71	7.60	.024	.102
Actual	18.43	16.05	87.09	7.88	.026	.135

Difficulties in Sampling Cane

The results in the preceding tables are considered to be very satisfactory considering the difficulties and odds against accuracy in this work. The sources of errors and the odds are enumerated below to show that it is a real task to present a true picture of the relative quality of the various fields of cane. It has been estimated that an average field of H 109 cane produces about 25,000 stalks of millable cane per acre and when 3 stalks are taken to represent an area of about 20 acres there are great odds against accuracy.

(1) Odds against number of stalks.
  Example: A 150-acre field would average 37,500,000 stalks of H 109. This total number of stalks would be represented by 21 sample stalks.
(2) Errors in the selection of representative sampling areas in a field.
(3) Errors in the selection of representative sample stalks within these areas.
(4) Unlike cane for comparison in that the pre-harvest cane consists of normal, sound stalks whereas harvested cane from the field includes cane in all stages of maturity and decay, degree of soundness, sucker growth and lala cane. This point is fully discussed further along in the paper.
(5) Comparison of unburnt pre-harvest cane with the burnt harvested cane entering the factory.
(6) Small-stalk canes of the D 1135 and P. O. J. 36 types are more difficult to sample than the H 109 type.
(7) Effect of climatic factors on juice qualities during the harvest period of the field.
(8) Errors in reading of the hydrometer or Brix spindle and polariscope.
(9) Changing value of the factor used in translating the "Cuba A" mill analyses over to the commercial mill basis. This happens when conditions change for either mill.

Problems of Field Sampling

Cane sampling has sometimes been called an art based only on the intelligence of those who take the samples. This art, however, may advantageously be placed on a systematic basis with a definite procedure as a result of careful study and experience, and it then becomes a technique. The pre-harvest sampling technique

employed at the Oahu Sugar Company, Ltd., and worked out by the author, has been proven to be successful and is described in the following paragraphs.

Originally, sampling consisted of carload lots of cane harvested wherever the railroad track happened to be in the field. Under this method samples could not be taken before the grinding season. They were not representative of the field and only showed the relative ripeness of the field at the point of sampling. Since it was proven here that 10 stalks of cane sampled at random next to the carload sampling area gave similar results in one-twelfth of the time and at a much lower cost, the carload sampling method was rapidly replaced by the systematic pre-harvest method which had since been considerably developed. (Note: Pre-harvest sampling was first started on this plantation in September, 1925.)

One of the outstanding problems is the correct sampling of irregular fields in order to show the average quality. Inaccessibility, with a resultant loss of time, offers another difficulty in field sampling in that all important points necessary for a true average of field conditions may not be covered. When these conditions are too severe, it is not advisable to sample. In addition to these difficulties are those reviewed under "Difficulties in Sampling Cane."

Sampling Technique

In our sampling technique, the fields for the ensuing crop are arranged in the order of a tentative harvesting schedule which is determined by the management. Cane sampling of the respective fields starts in August for all except the group of short ratoon fields, and is conducted at monthly intervals until the harvest period of each field. Each field is sampled at about the same date of each succeeding month in order to give a proper time interval. If the sampling date falls within a week of the beginning of the harvest of the field in question, the sampling results are considered as final, otherwise an extra sample is taken a few days prior to the field harvest. Very often an extra sample is taken of several fields as a guide to "what field shall be harvested next." This is particularly true when a group of fields have been running close together in their juice qualities for some time, after which heavy showers of rain would tend to bring down the juice qualities of some fields faster than others.

By sampling our fields 4 months prior to the beginning of harvest, we are able to get 4 points on a curve to show the trend of ripening. This information can serve as a guide to the management in determining what changes, if any, should be made in the order of harvesting fields.

The number of representative sampling areas selected in a field is dependent on the size and uniformity of the field. Within every 15 to 25 acres of this field, a representative area for sampling, consisting of about 10 lines, is located from 75 to 100 feet from the edge of the field road, trail, supply ditch or any other type of boundary. Where spot irrigation is practiced, these sites are established deep enough into the field to avoid this unusual condition. Sampling sites are conveniently marked so that they can be readily located at subsequent periods of sampling. A new row of cane is sampled at each interval.

The sampling rows are divided into three sections and a stalk of cane is picked at random from the middle of each section, thus giving 3 stalks per row per site per field unit (15 to 25 acres). This method gives us a true average of the cane in the row. Through experimentation we have found that the end sections of a cane row have heavier cane but poorer juice while the middle section has lighter cane and better juice.

In selecting a stalk of cane, the sampler uncovers some of the trash at the bottom of the row and traces the stalk out to its leafy top to see that it is a normal, sound stalk, free of tassel and lalas. He then cuts it off flush with the bottom of the row, using a short keyhole saw, and tops it at a point similar to that done in the harvesting field. The stalks are cut in convenient lengths for dragging them out of the field.

The various areas are sampled until the entire field has been covered, after which the samples are taken to the mill to be measured, weighed and crushed. The total length and total weight are determined, which, divided by the number of stalks, give the average length and weight per stalk. The cane is crushed in a Cuba A mill and a representative sample of the extracted juice is taken to the laboratory for analysis. Sampling is done carefully and as rapidly as possible. During rainy weather the cane is wiped free of mud and moisture before it is crushed.

Correct selection of cane stalks is most important and is also difficult since there is such a great variation between them. Consistent results cannot be obtained unless great care is used in cutting the cane at the ground level and topping it at the same relative point. It has been proven through experimentation that the results can be altered by incorrect cutting and topping of cane. Stalks are found in various stages of maturity and ripeness and there is also a certain amount of defective cane due to various causes. Not knowing the proportion of these classes of cane stalks plus undetermined sucker growth, which affect cane yields and juice qualities, the best method is to select normal, healthy, non-tasseled stalks at random in the cane row as described in the foregoing paragraph. In this way, all the fields are placed on a common basis for relative comparison.

Pre-Harvest Data

Variation between the results of the final pre-harvest samples and final field analyses, provided that the correct technique has been followed in sampling, is attributable to such factors as: (1) dead, partly rotted or insect-infested cane, the amount of which varies according to field conditions and varietal characteristics; (2) sucker growth; (3) amount of tasseled stalks; (4) climatic influence in the interim between the pre-harvest sampling date and period of field harvesting; and (5) burnt cane versus unburnt cane.

The data on pre-harvest cane sampling is presented in reports which are in the following form, two examples of which are shown:

REPORT I

OAHU SUGAR COMPANY, LTD.

JUICE ANALYSES OF PRE-HARVEST CANE SAMPLES

Field 20 H 109—Long 4th Ratoon 1931 Crop

Date	Brix	Pol.	Purity	% P_2O_5	% K_2O	Average Length per Stalk	Average Weight per Stalk Pounds	Weight per Foot Pound
				CUBA "A" MILL ANALYSES				
3/ 2/31	19.77	18.00	91.05	.020	.057	16.21′	9.00	0.56
2/15/31	19.50	17.73	90.92	.020	.068	15.52′	8.76	0.56
1/12/31	17.99	16.19	89.99	.015	.066	15.92′	9.26	0.58
12/ 5/30	17.13	14.89	86.92	.022	.076	15.48′	8.95	0.58
11/20/30	16.00	14.12	88.20	.015	.057	14.22′	7.43	0.52
10/27/30	14.70	11.80	80.27	.017	.063	13.59′	7.86	0.58
9/17/30	15.38	12.78	83.10	.0175	.090	12.00′	7.14	0.60

WAIPAHU ANALYSES

Date	Brix	Pol.	Purity	Cane Ratio
3/ 2/31	19.77	17.50	88.52	7.12
2/15/31	19.50	17.23	88.36	7.27
1/12/31	17.99	15.74	87.49	7.97
12/ 5/30	17.13	14.47	84.47	8.89
11/20/30	16.00	13.72	85.70	9.27
10/27/30	14.70	11.47	78.03	11.94
9/17/30	15.38	12.42	80.42	10.67

REPORT II

OAHU SUGAR COMPANY, LTD.

JUICE ANALYSES OF PRE-HARVEST CANE SAMPLES

Field 44 H 109—Long 4th Ratoon 1932 Crop

Date	Brix	Pol'n	Purity	Cane Ratio	Glucose	% Standard Ripeness	K_2O % Juice
			CUBA "A" MILL ANALYSES				
9/14/31	16.55	14.40	87.01		1.10	52.4	.089
8/18/31	16.41	14.15	86.25		0.93	60.8	.078

COMMERCIAL MILL CONVERSION

Date	Brix	Pol'n	Purity	Cane Ratio	Age of Cane	Average Stalk Length Feet	Average Stalk Weight Pounds	Weight per Ft. Cane Pound
9/14/31	16.55	14.00	84.59	9.18	16 Mos.	11.83	7.08	0.60
8/18/31	16.41	13.75	83.79	9.38	15 Mos.	10.98	6.08	0.55

Under Report I are the results of pre-harvest sampling for one of the fields of the 1931 crop to show the progress of cane ripening. The report shows the rela-

tive difference between the analyses of the Cuba A mill crushings and that of the commercial mill as determined by the correction factor. The factor which is used for our conditions in order to change the Cuba A mill juice over to our commercial mill basis is 97.2, i.e., 97.2 per cent of the Cuba A mill polarization gives an approximately correct figure for polarization to represent actual conditions. The Brix from the Cuba A mill is so close to the actual that a correction factor makes no difference. It will be necessary for each plantation to work out its own factor of correction. There is a steady improvement in the juice quality of the field from the time sampling was started till the harvest period of March 6-16, 1931, with one exception. The influence of weather along with the final irrigation of the field brought down the juice quality for the month of October. The statistics on stalks of cane are interesting in that they give one an idea of the quantity of cane in terms of growth. At time of harvest, the cane was 21¾ months old so that it is reasonable to believe the cane to be nearly 16 feet in length at an average weight of 0.56 pound per foot. The average weight per foot of H 109 cane for a five-year period of all classes of H 109 is 0.58 pound. None of the stalk statistics shown in Report I correlate with final cane yields because of the variation in the number and kind of stalks per line.

Beginning with the 1932 crop, the reports have been changed somewhat as shown in Report II. We have come to the conclusion that it is not necessary to show P_2O_5 per cent Brix any more since the figure is fairly constant for all classes of cane and fertilizer practices. Potash varies a great deal depending on variety and treatment of cane so it is interesting to know the relative amounts absorbed for different conditions. Age of cane at various periods of sampling has certain value. A new method of measuring relative juice quality is the factor called the "Standard of Ripeness" which was devised by H. W. Robbins, chief chemist of the Oahu Sugar Company. Standard of Ripeness is a more accurate means of measuring the real ripeness of a field from time to time. This is best explained by quoting from Mr. Robbins' report entitled: "The Quality of Cane and Cane Ripening."

When making a study of cane quality and ripening it is necessary to have a standard that will serve for comparison of different varieties of cane, and of cane grown under all conditions. The cane ratio is the measure most generally used in estimating the quality of cane. This ratio is calculated from the sucrose content of the cane and the purity of the cane juice, and is a ratio of quantity. When used with a known weight of cane it indicates quality. When the weight of the cane is not known, as in pre-harvest juice sampling, it cannot correctly be used as an indication of quality. The sucrose content of the cane is influenced by the water content, resulting in a high or low cane ratio, so that the cane ratio may be high or low due to more or less water in the cane.

The purity of the juice of the cane, being the pol expressed in percentage of the total solids in solution, is not influenced by the water content of the cane. Purity, however, being on the basis of solids in solution can be influenced by the nature of the solids other than sucrose. When the cane is approaching ripeness the sucrose content of the juice is high while that of the non-crystallizable sugars (glucose) is low. Ordinarily this condition results in a high purity, indicating ripeness. If, however, this cane should contain a large amount of solids in solution not sugars, the purity would be lower and not indicate the condition of ripeness. An example of this is D 1135 cane, the juice of which contains quite generally twice as much potash in solution as the juice of H 109. Our

records show the non-sugars of D 1135 to be 50 per cent more than that of H 109, and other varieties somewhat higher. High juice purities at maximum ripeness cannot be expected of these canes. Our records show also that there are fields on the plantation that produce cane with juice of high non-sugar content as compared with the same variety of cane in other fields.

For the purpose of making comparisons of ripeness the ratio of glucose to polarization is useful. A standard ratio may be used. We have taken a ratio of 25 equal to a standard ripeness of 100. It is assumed that any system of ripening cane will affect this ratio, while the ratio of non-sugars to pol is due to other factors. The non-sugars are taken as the difference between sum of the pol and the glucose, and the total solids in solution as determined by the Brix hydrometer. The figures for non-sugars include the errors of difference between pol and sucrose and the differences between true solids and Brix solids. As these differences are somewhat constant, the figure has some value in a study of this nature.

Examples of this method of estimating the ripeness of cane are given from the field records of the crop of 1931 and the average of all fields of the crop of 1930.

		Crusher Juice			Per 100 Brix			Glucose		
							Non-	Pol	Standard	Cane
Field	Variety	Brix	Pol	Purity	Pol	Glucose	Sugars	Ratio	Ripeness	Ratio
3-B	D 1135	17.12	14.25	83.2	83.2	4.6	12.2	18.09	72.4	8.92
52	H 109	17.50	15.38	87.9	87.9	4.5	7.6	19.53	78.1	7.89
53	H 109	16.80	13.77	82.0	82.0	7.2	10.8	11.39	45.6	9.38
45-A	H 109	19.40	17.85	92.0	92.0	2.5	5.5	36.80	147.2	6.73
Ave. 1930		18.19	16.09	88.4	88.4	3.6	8.0	24.55	97.5	7.92

These are extremes of juice purities and the standard ripeness figure follows the purity, but not in the same proportion.

Below is given the application of this method to two varieties of cane grown on adjoining plots of .40 acre area each at the H. S. P. A. Waipio substation. The two canes were planted, irrigated, fertilized and harvested at the same time.

	Crusher Juice			Per 100 Brix			Glucose	
						Non-	Pol	Standard
Variety	Brix	Pol	Purity	Pol	Glucose	Sugars	Ratio	Ripeness
H 109	20.01	17.53	87.6	87.6	4.4	8.0	19.92	79.7
Y. Caledonia	19.45	15.78	81.1	81.1	5.0	13.9	16.22	64.9

This illustrates the effect on the juice of a similar practice of growing cane when applied to two varieties. The glucose determinations and the non-sugars, by difference, give some explanation for the juice of Yellow Caledonia being so much lower than that of H 109.

Summary

Pre-Harvest Juice Sampling

Object:

To secure such samples from a field that a reasonably accurate prediction may be made of the average quality of cane when harvested.

Number and Location of Sampling Areas:

The number of sampling areas and their locations must be such that in each group of sample stalks from that field there will be a proportionate number from

each class of soil and terrain, i.e., light or heavy soils, pali, bottom, slope or flat. Sampling areas should be at least 100 feet from edge of field, or any field road, trail or ditch.

Size of Sampling Area:

Each sampling area should have about 10 lines. This should represent an area not larger than 25 acres or less than 15 acres, depending upon conditions.

Marking of Sampling Areas:

Each sampling area should be clearly marked so that it may be found readily when samples are to be taken.

Taking Samples:

Three sound sticks of cane should be taken from one row in each sampling area for each sample. Avoid extreme ends of row. Take one stick at each of three points in the line. Cut cane cleanly at or below ground and always top sticks at same relative point; this is important. Avoid suckers or tasseled stalks. Keep the sample group from each field separate and clearly mark. Remember that the results of the entire work depend on the care used in sampling and the validity of the group samples as representing the field.

Preparation for Milling Sample:

Sample stalks are weighed and measured to give average length and weight per foot. In wet weather, stalks should be wiped clean.

Milling Sample:

Samples are milled in a small Cuba A mill, using care to see that juices are accurately separated. Juice samples should be taken frequently and analyzed as soon as possible.

Conversion Factor:

A conversion factor is necessary to translate the results of the sample into terms of the lower purity juice which results from commercial mill work. This factor will have to be developed from experience for each plantation. (Oahu factor for purity is 97.2 per cent. Brix need not be corrected.)

Results of Sampling Fields:

After six years of development of the technique of sampling, there is a high degree of correlation between the last field sample and the quality of the cane when harvested.

Temperature, Rainfall and Sunshine Data of Hawaiian Sugar Plantations

COMPILED BY U. K. DAS

1. Foreword.
2. Climatic characteristics of the Hawaiian Islands.
3. Temperature data:
   - Annual temperature.
   - Seasonal temperature.
   - Monthly average temperature.
   - Mean daily range of temperature.
   - Extremes of monthly temperature.
   - Temperature departures from average (1905-1930).
4. Rainfall data:
   - Normal monthly rainfall.
   - Extremes of monthly rainfall.
   - Rainfall departures from normal (1905-1930).
5. Sunshine data.

FOREWORD

An intensive study of the factors in sugar production must take into consideration the part played by weather conditions: temperature, sunshine, rainfall, etc. There is as yet very little systematic and organized knowledge available of the climate of our sugar plantations. Such knowledge would appear to be the more needed at this time, for a dispassionate study of the relation of our cultural practices to the increased yields of recent years must start by eliminating the effects of changed weather conditions.

In this paper, we have brought together in a convenient form some climatic data for the last 26 years (1905-1930) of the sugar plantations of the Territory. The data are far from being adequate at present, but it is hoped that this paper will stimulate interest in the recording and study of weather data, so that in years to come we shall know quite as much about the effects of weather conditions on sugar production as we do of the effects of fertilizers, irrigation water, etc.

Special thanks are due J. F. Voorhees, of the U. S. Weather Bureau at Honolulu, for placing at our disposal the complete files from which most of the original data were taken, and also for valuable help and criticism.

We would appreciate our attention being drawn to errors and omissions in this text.

CLIMATIC CHARACTERISTICS OF THE HAWAIIAN ISLANDS

An excellent account of the climatic characteristics of these islands may be found in the "Summary of the Climatological Data" for the Hawaiian section published by the U. S. Weather Bureau in 1918, copies of which publication are available at the office of the Weather Bureau at Honolulu.

The following extracts are taken from the said publication:

The rainfall of the Hawaiian Islands belongs to a simple type, being due mostly to the forced ascent of the northeast trades by the mountains they encounter. Usually, therefore, heavy rains fall on the windward slopes. This condition, however, is reversed during the prevalence of the so-called kona storms.

Temperature is a much simpler factor to study than precipitation, depending almost entirely as it does on elevation, although affected in a minor way by the slope and exposure to the wind. The range of mean monthly temperature from summer to winter in the lower levels throughout the island is slight and simple of analysis, while the drop in temperature from sea level to the highest elevations corresponds closely to what might be expected of temperature gradients in the tropics (Temperature decrease of 1° F. for each 300 ft.).

The outstanding features of Hawaiian climatology are the remarkable differences in the quantity of precipitation gaged in adjacent areas, the tenaciousness of the trade winds through all seasons and over all islands of the group (aside from a limited area leeward of Haleakala and over the kona districts of Hawaii), and the persistently equable temperature which passes through the cycle of seasons devoid of extremes. The abundant sunshine, especially over the leeward slopes, and the lack of tropical storms, known elsewhere in the tropics as typhoons or hurricanes, add to the desirability of the climate from the standpoint of recreation and pleasure as well as the more practical pursuits of life.

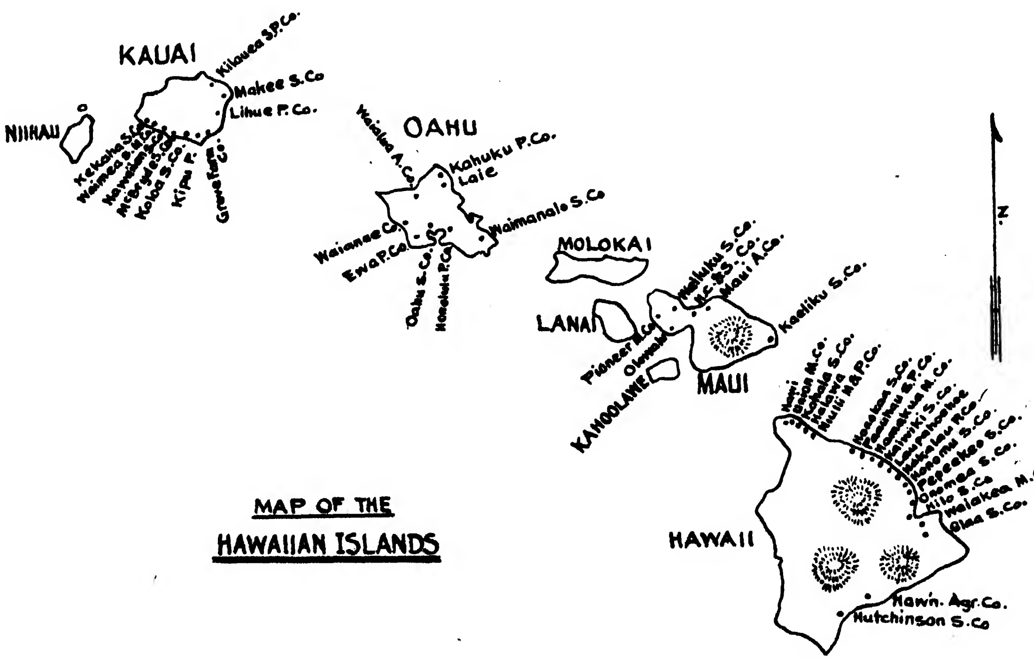


Fig. 1. Map showing the location of the sugar plantations.

SUMMARY OF CLIMATIC DATA OF THE SUGAR PLANTATIONS

Weather Station	Elevation in Feet	Annual Mean Max. Temp. Fahr.	Annual Mean Min. Temp. Fahr.	Mean Daily range of Temp.	Mean Annual Rainfall
OAHU					
Ewa Mill	50	83.0°	64.6°	18.4	20.75
Kahuku	25	80.9	68.0	12.9	37.62
Waialua	30	82.6	63.7	18.9	30.76
Waianae	6	85.2	66.4	18.8	19.78
Waimanalo	25	81.7	68.9	12.8	43.83
Waipahu	200	82.5	65.9	16.6	24.31
MAUI					
Hana	200	80.3	67.5	12.8	75.21
Kaanapali	12	84.8	65.8	19.0	18.30
Lahaina	30	....	....	....	12.13
Puunene	..	82.9	66.8	....	.....
Wailuku	206	81.4	67.1	14.3	28.94
KAUAI					
Eleele	150	81.2	66.3	14.9	29.63
Grove Farm	200	....	....	....	48.13
Kealia	14	81.7	67.5	14.2	39.91
Kekaha	8	....	....	....	22.28
Kilauea	342	79.7	65.8	13.9	68.72
Koloa	241	79.8	66.5	13.3	64.17
Lihue	200	80.6	65.5	14.9	53.17
Makaweli	140	83.2	66.3	16.8	22.81
HAWAII					
Hakalau	200	78.9	65.8	13.1	147.04
Hilo	40	79.8	65.3	14.5	141.03
Honokaa Mill	461	80.2	64.1	16.1	78.48
Kohala	309	79.6	65.6	14.0	58.56
Naalehu	650	....	....	....	43.14
Niulii	85	....	....	....	61.95
Olaa Mill	225	81.8	63.1	16.7	141.06
Ookala	400	79.8	65.1	13.9	118.69
Paauhau	400	....	....	....	69.70
Paauilo	400	....	....	....	94.89
Pahala	850	81.1	61.4	19.7	44.26
Papaikou	250	....	....	....	182.87
Pepeekeo	100	79.8	65.8	14.0	128.24

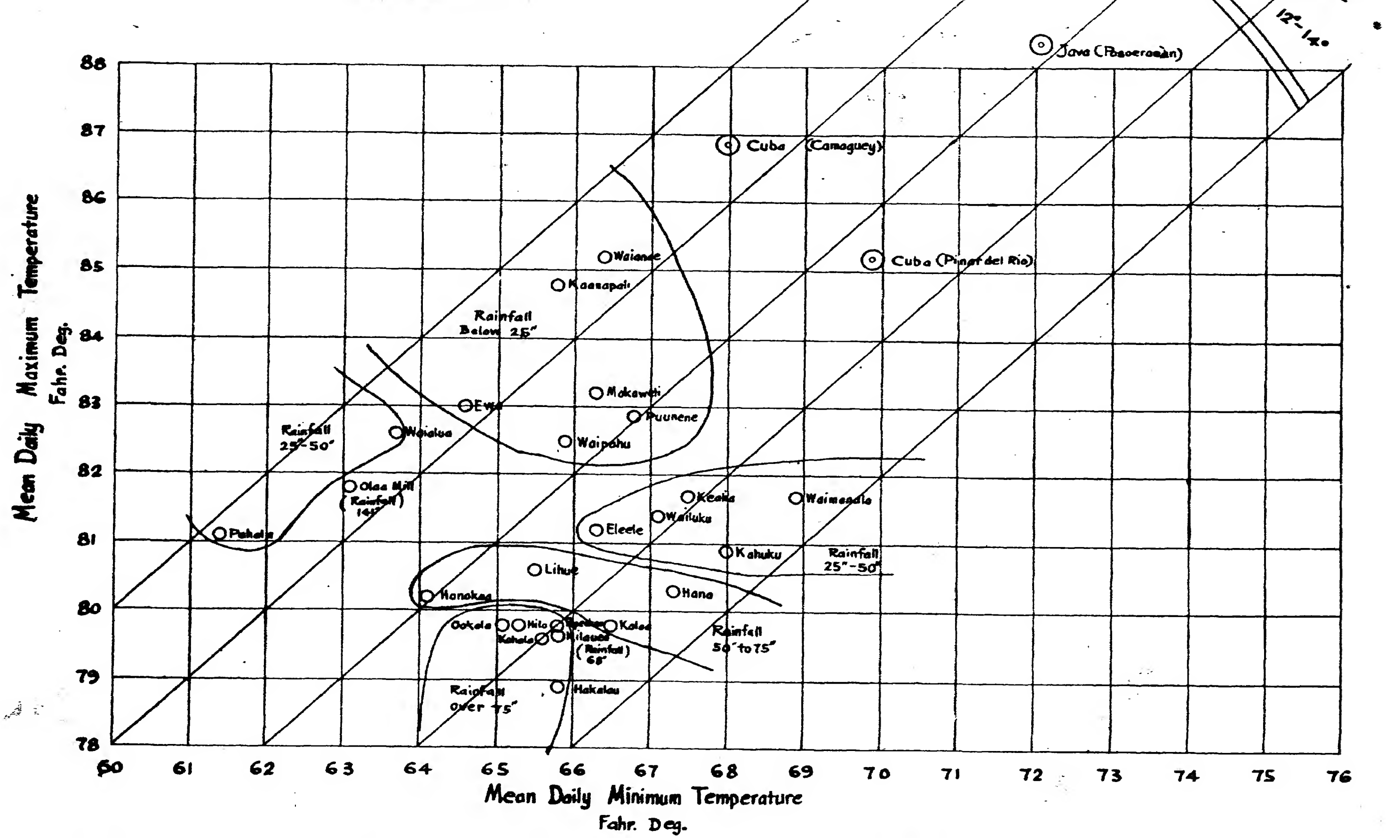
Temperature Data

The records of temperature from 1905-1930 are available for only 23 plantations of the Territory.

The data are presented as maximum or minimum temperature, for our studies indicate that in the understanding of the relation of cane growth to temperature, the maximum and the minimum temperatures are better guides than the mean temperature.

A Climatic Segregation of Hawaiian Sugar Plantations

Data (1905 - 1930)



Note :- Plantations noted for poor juices have the lowest daily range of temperature

Fig. 2

Annual Mean Temperature:

Table A (Fig. 3) gives the annual mean maximum and annual mean minimum temperatures of the different stations. It will be noted that in general the leeward plantations are warmer than the windward plantations.

Annual Mean Maximum And Mean Minimum Temperature

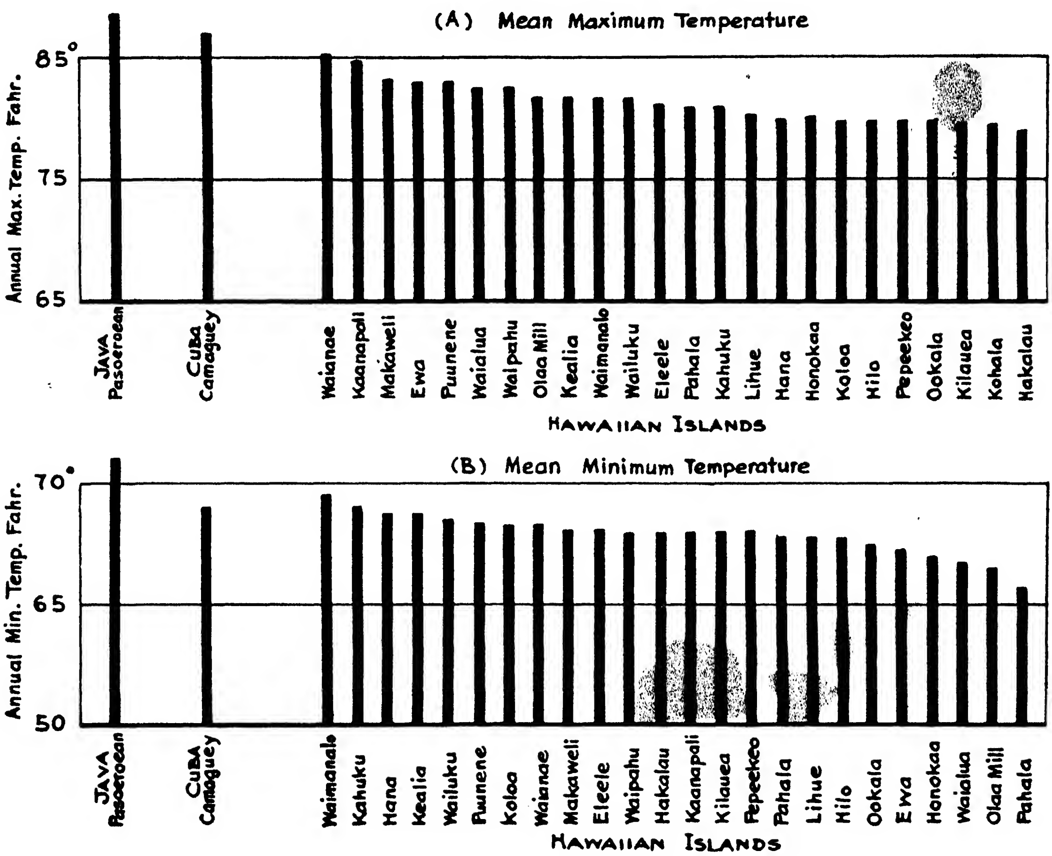


Fig. 3

Seasonal Temperature:

Table B (Fig. 4) shows the seasonal temperatures, arranged in the descending order of warmth. Seasonal means have been computed by taking January, February and March as the winter months, April, May and June as the spring months, and so on; for, in these islands, January, February and March are the coldest months, December being warmer than March. The seasonal temperatures of Java and Cuba are given for the sake of comparison.

Fig. 4 brings out some interesting differences between the plantations. Some places are comparatively warm or cold throughout all the seasons, while others are warm in some seasons and cold in others. For example—Ewa Mill (Fig. 4-A) is about the fourth warmest plantation throughout the four seasons, while Olaa mill is third warmest in winter, but only twelfth warmest in summer. Hakalau, on the other hand, is uniformly the coldest of all the plantations recorded herein.

If we compare the temperature of Java and Cuba with that of our plantations (Fig. 3) we will notice a great difference. This difference is of even greater significance than is apparent. If we assume that sugar cane grows little or none at all below a mean maximum temperature of 65°, then we see that the "active" temperature (i.e., temperature over 65°) of Waianae—our warmest plantation—is only 87 per cent of Java temperature. Table C gives the annual mean maximum temperatures of Hawaiian plantations calculated as percentages of Java temperature.

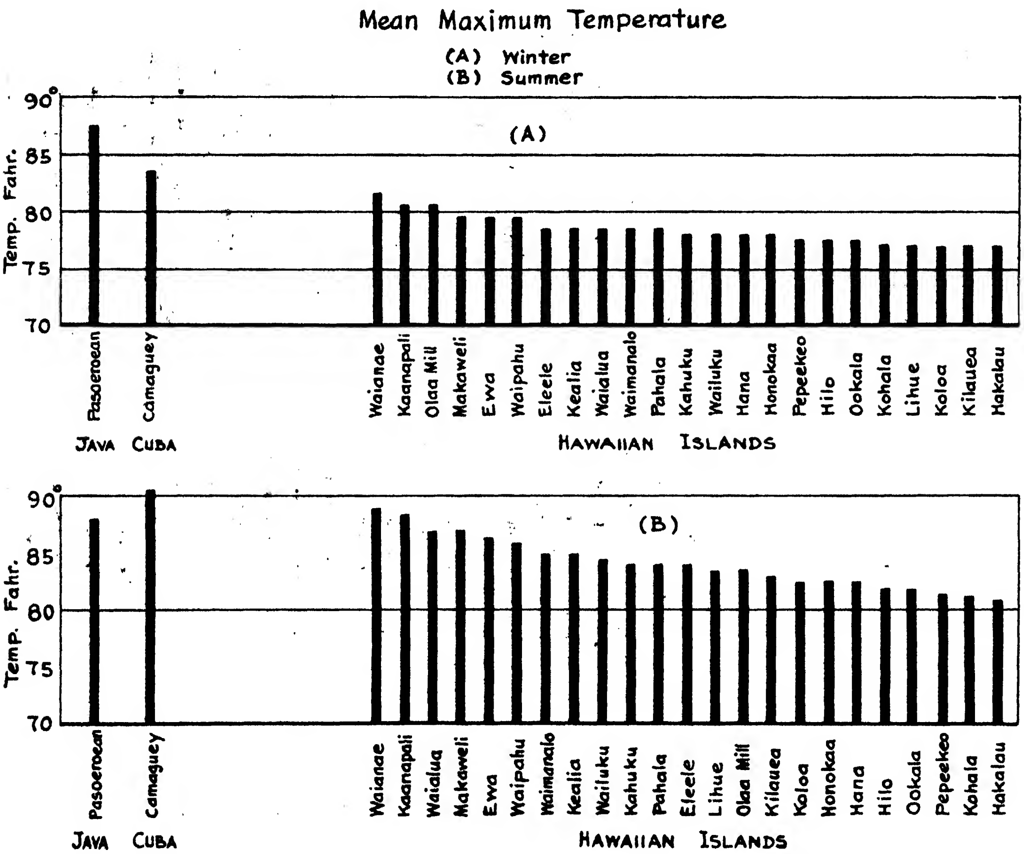


Fig. 4-A

Monthly Average Temperatures:

Table D gives the average mean maximum and average mean minimum temperatures by months. Table E shows the departures from the average of each month of 1905-1930. It is believed that the presentation of the temperature data as departures from the average rather than in absolute figures will facilitate the study of the relation of temperature to cane growth or sugar production. Should it be desired to find the temperature of any month, it can easily be done by adding the departure for the month in question to the average of that month.

There are several ways in which the tables could be made use of. Plantations may find it of advantage to plot the monthly temperatures for each crop on a wall chart similar to Fig. 5. This chart will show at a glance whether the weather

conditions have been favorable or otherwise for cane growth, whether this year's crop should be behind or ahead of last year's, etc. It will further be of assistance in estimating yields, in arriving at decisions regarding particular field culture.

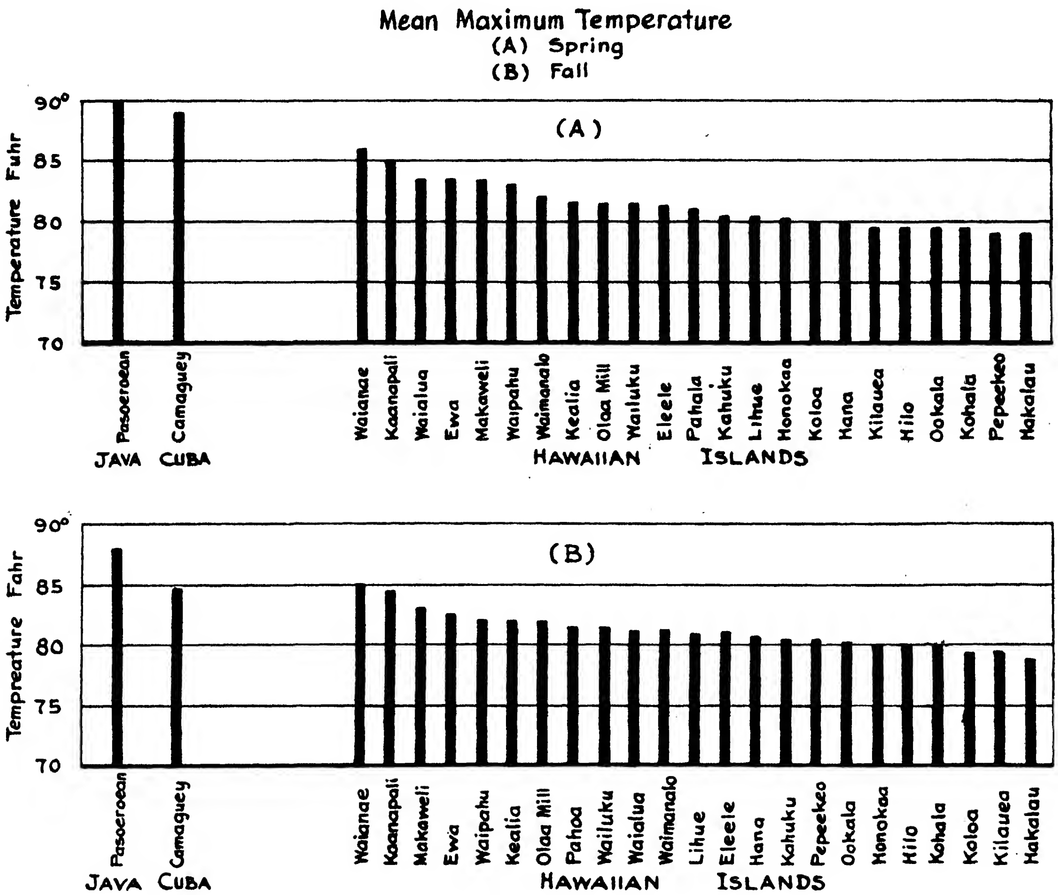


Fig. 4-B

We feel that the great significance of temperature changes to sugar production is not sufficiently realized by all the plantations—possibly because the temperature differences are not as apparent as the difference in the amount of rainfall from one season to another. While we are likely to notice a difference of 2 to 3 inches in rainfall, we hardly notice a difference of 2° to 3° in temperature. Yet in many cases, this imperceptible, but none the less significant, difference in temperature may influence our crop production to a far greater degree than the difference in rainfall.

Many growth studies conducted by the plantations and by the Experiment Station have demonstrated the close relation between temperature and cane growth. Our weather studies have shown clearly that the observed relation between temperature and cane growth can explain the fluctuations in yield per acre of the plantation crops as well. Fig. 6 shows very clearly the differences in temperature between the years of high yield and years of low yield of one of our typical unirrigated plantations.

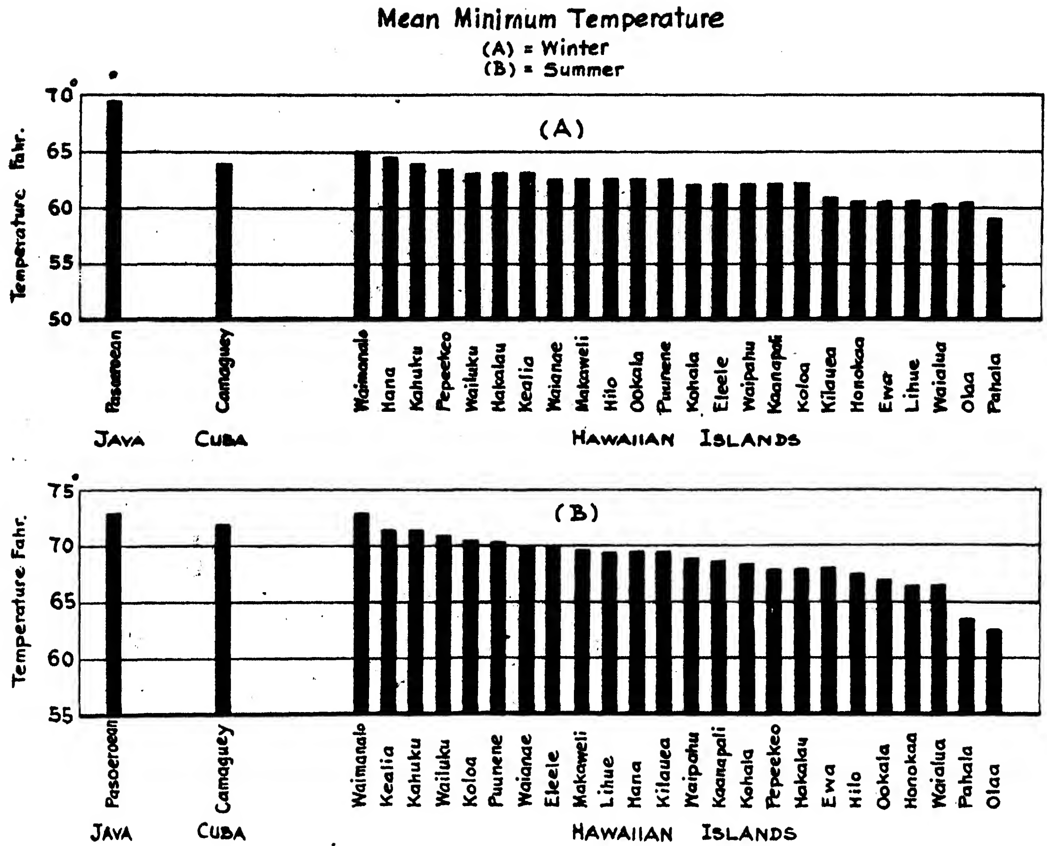


Fig. 4-C

Our studies have further shown that the temperature conditions in the first season are of greater importance than at any other subsequent period, probably because it is in the first season that the canes are growing, by nature, at a fast rate and that it is in the first season that the stand is being established. It is of great interest to note that the recent record yields of three of our typically well-irrigated plantations were associated with record temperatures in the first season.

Ewa had its record yield per acre in 1925. The mean maximum temperature in the fall months of 1923 (i.e., in the first season) were the highest on record. Oahu Sugar Company's record yield in 1928 was preceded by record temperature in the fall months of 1926 and the winter of 1927; Waialua's record yield of 1929 was similarly preceded by record temperatures in the fall months of 1927.

There are other information of practical benefit that we can gather from a close study of the temperature data. What, for instance, is the relation between temperature changes and periodic infestation of insect pests or fungus diseases? We hear of typical eye spot weather—are there typical weathers for other diseases as well? Again, a progressive plantation may want to take advantage of warm growing weather by applying more fertilizer or more water to the field, how will it know except by close study of the temperature data that one month of high temperature is likely to be followed by one or more months of high tem-

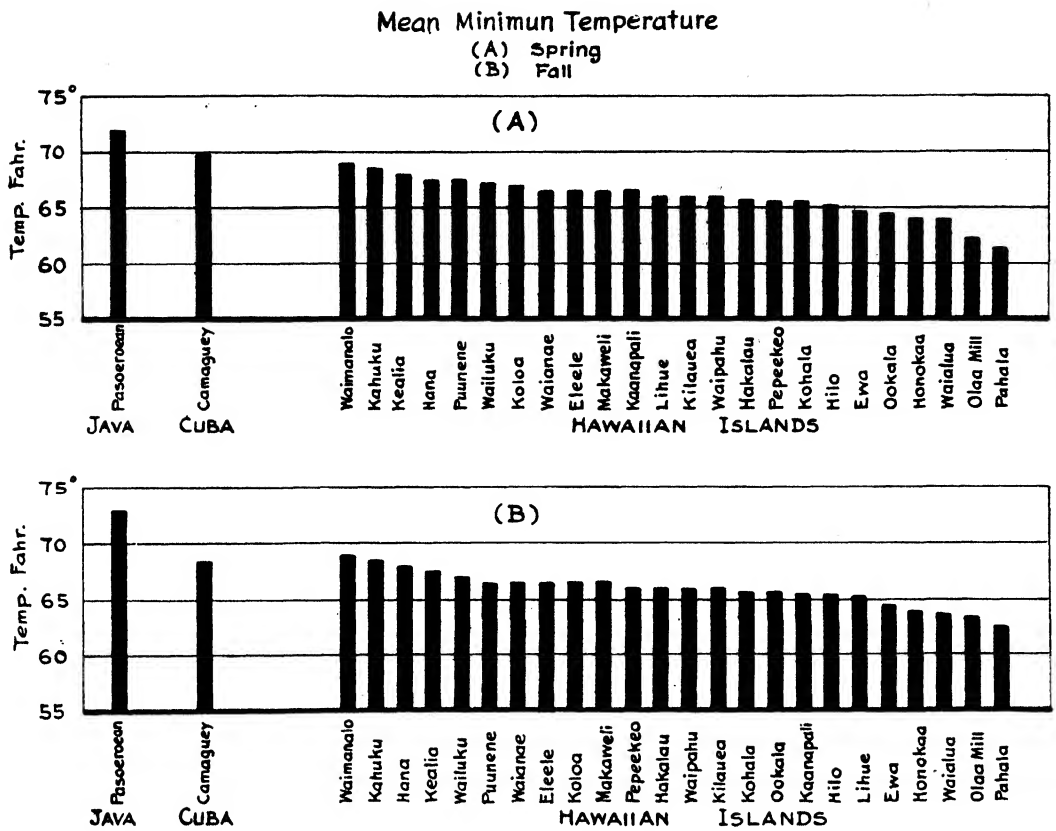

Mean Minimun Temperature
(A) Spring
(B) Fall
(A)
Temp. Fahr.
75°
70
65
60
55
Pasoeroean
Camaguey
Waimanalo
Kahuku
Kealia
Hana
Puunene
Wailuku
Koloa
Waianae
Eleele
Makaweli
Kaanapali
Lihue
Kilauea
Waipahu
Hakalau
Pepeekeo
Kohala
Hilo
Ewa
Ookala
Honokaa
Waialua
Olaa Mill
Pahala
JAVA
CUBA
HAWAIIAN ISLANDS
(B)
Temp. Fahr.
75°
70
65
60
55
Pasoeroean
Camaguey
Waimanalo
Kahuku
Hana
Kealia
Wailuku
Puunene
Waianae
Eleele
Koloa
Makaweli
Pepeekeo
Hakalau
Waipahu
Kilauea
Kohala
Ookala
Kaanapali
Hilo
Lihue
Ewa
Honokaa
Waialua
Olaa Mill
Pahala
JAVA
CUBA
HAWAIIAN ISLANDS

Fig. 4-D

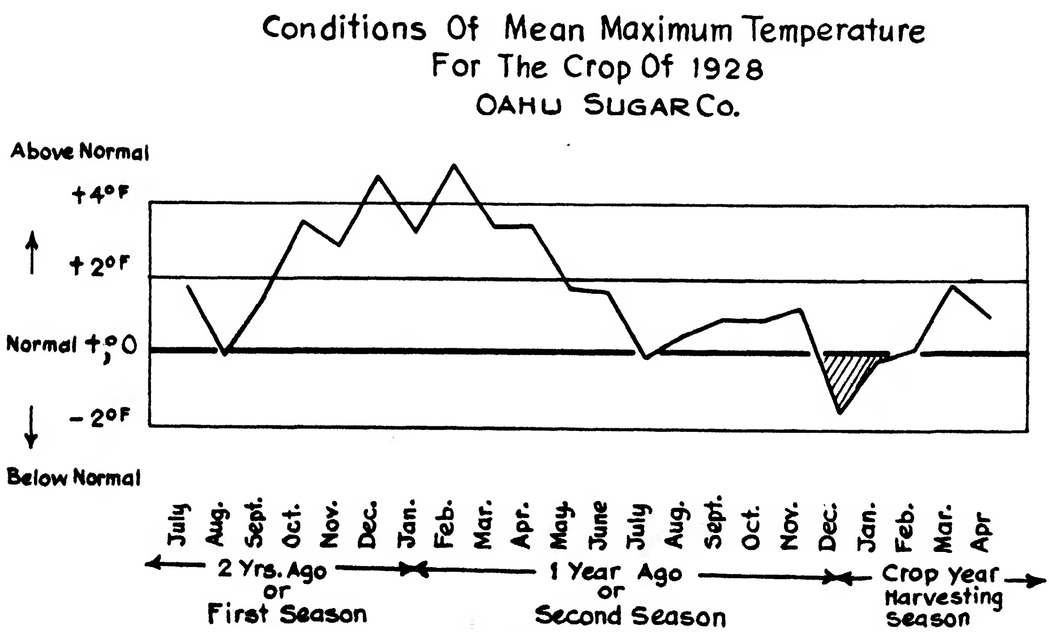

Conditions Of Mean Maximum Temperature
For The Crop Of 1928
OAHU SUGAR Co.
Above Normal
+4°F
+2°F
Normal +,0
-2°F
Below Normal
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr
2 Yrs. Ago or First Season
1 Year Ago or Second Season
Crop Year Harvesting Season

Fig. 5

perature? Indeed, a casual study of the tables does show that warm and cold months generally come together in periodic fluctuations.

These introductory notes are mainly written in answer to oft-repeated questions—"Of what use are all these weather data?" "We can't do anything about our weather." Surely not, but by studying our weather we may know more about its ways and when the good weather comes we shall know and take advantage of it, and when the weather is against us, then also we shall know of it and know why our yields decrease and thus save ourselves unnecessary worry. We believe very strongly that plantations will find it of practical benefit to record weather data and make intelligent use of it.

A word of caution is necessary against the limitations of the data presented herein. We have only one weather station representing a plantation. The data from this one station may not apply to the whole plantation because of local differences in the different sections of its lands.

Range of Temperature

Table F gives the mean daily range of temperature from 1905-1930 (range of temperature is equal to the difference between the average daily maximum and average daily minimum temperature). In Fig. 7 the plantations are arranged in descending order of their annual daily range of temperature.

Our previous studies indicate that range of temperature has a close relation to juice quality and possibly to cane production.* It will be noted in Fig. 7 that the plantations noted for poor juices have generally a low daily range of temperature.

Extremes of Temperature

Table G gives the monthly extremes of temperatures for the years 1905-1930. These extremes are of interest in that they indicate how high or low a temperature we may expect in a particular month and what this difference means in terms of cane growth or sugar yield.

It will be noted that some plantations are more subject to extreme fluctuations than others. Waimanalo, for instance, has about the same extremes of mean maximum temperature in August as Ewa, but the average mean maximum of Ewa for that month is 1.4° higher than Waimanalo's.

---

* There are reasons to believe that the positive correlation between daily range of temperature and juice quality holds true only within certain temperature limits. Under conditions of extreme maximum or minimum temperature the normal physiological processes may be greatly disturbed. Under those limiting conditions, range of temperature alone may fail to account for the quality of juice.

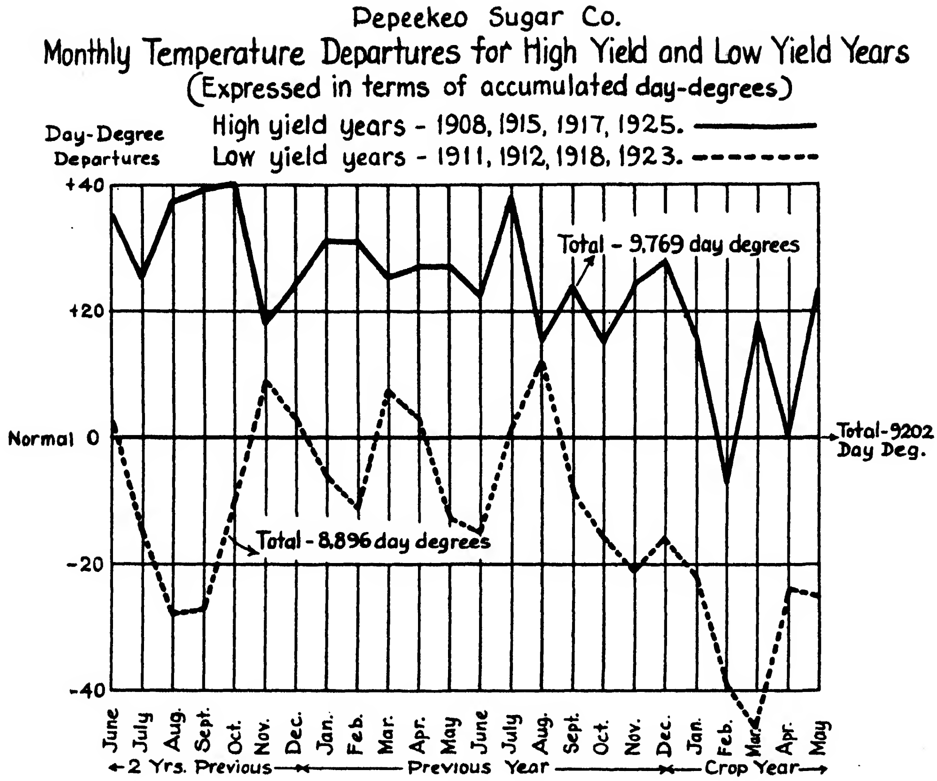

Depeekeo Sugar Co.
Monthly Temperature Departures for High Yield and Low Yield Years
(Expressed in terms of accumulated day-degrees)
Day-Degree Departures
High yield years - 1908, 1915, 1917, 1925.
Low yield years - 1911, 1912, 1918, 1923.
+40
+20
Normal 0
-20
-40
Total - 9,769 day degrees
Total - 8,896 day degrees
Total-9202 Day Deg.
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
2 Yrs. Previous
Previous Year
Crop Year

Fig. 6

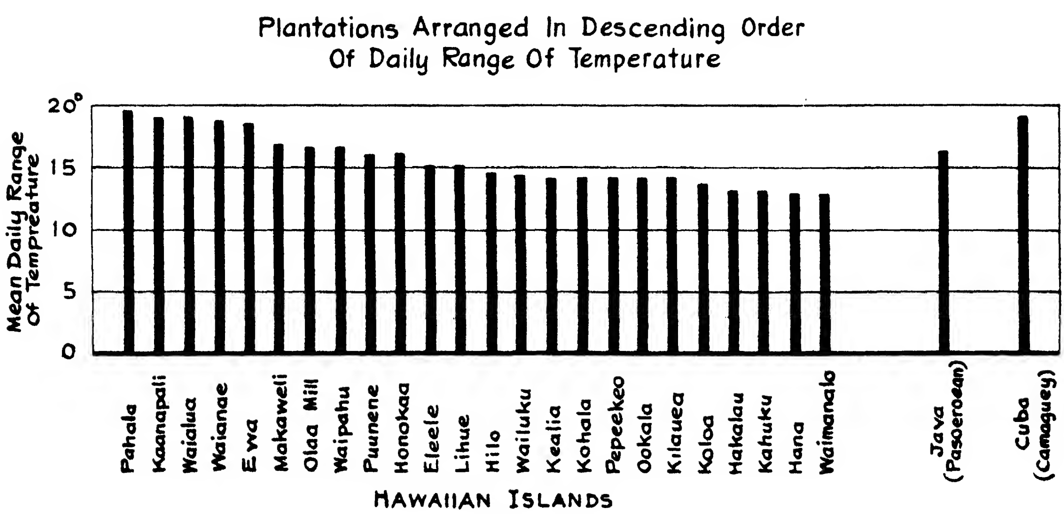

Plantations Arranged In Descending Order
Of Daily Range Of Temperature
Mean Daily Range Of Temperature
20°
15
10
5
0
Pahala
Kaanapali
Waialua
Waianae
Ewa
Makaweli
Olaa Mill
Waipahu
Puunene
Honokaa
Eleele
Lihue
Hilo
Wailuku
Kealia
Kohala
Pepeekeo
Ookala
Kilauea
Koloa
Hakalau
Kahuku
Hana
Waimanalo
Java (Pasoeroean)
Cuba (Camaguey)
HAWAIIAN ISLANDS

Fig. 7

TABLE A

Annual Mean Maximum and Mean Minimum Temperatures

Station	Mean Maximum Temperature	Station	Mean Minimum Temperature
Waianae	85.2	Waimanalo	68.9
Kaanapali	84.8	Kahuku	68.0
Makaweli	83.2	Hana	67.5
Ewa	83.0	Kealia	67.5
Puunene	82.9	Wailuku	67.1
Waialua	82.6	Puunene	66.8
Waipahu	82.5	Koloa	66.5
Olaa Mill	81.8	Waianae	66.4
Kealia	81.7	Makaweli	66.3
Waimanalo	81.7	Eleele	66.3
Wailuku	81.4	Waipahu	65.9
Eleele	81.2	Hakalau	65.8
Pahala	81.1	Kaanapali	65.8
Kahuku	80.9	Kilauea	65.8
Lihue	80.6	Pepeekeo	65.8
Hana	80.3	Kohala	65.6
Honokaa	80.2	Lihue	65.5
Koloa	79.8	Hilo	65.3
Hilo	79.8	Ookala	65.1
Pepeekeo	79.8	Ewa	64.6
Ookala	79.8	Honokaa	64.1
Kilauea	79.7	Waialua	63.7
Kohala	79.6	Olaa Mill	63.1
Hakalau	78.9	Pahala	61.4
Java (Pasocroean)	88.3	Java (Pasoeroean)	72.1
Cuba (Camaguey)	86.8	Cuba (Camaguey)	67.9

TABLE B-I

Seasonal Mean Maximum Temperature—Plantations Arranged in Descending Order of Temperature

Station	Winter Temperature	Station	Spring Temperature	Station	Summer Temperature	Station	Fall Temperature
Hawaiian Islands							
Waianae	81.3	Waianae	85.4	Waianae	89.0	Waianae	85.1
Kaanapali	80.6	Kaanapali	85.0	Kaanapali	88.8	Kaanapali	84.6
Olaa	80.6	Waialua	83.6	Waialua	86.9	Makaweli	83.1
Makaweli	79.5	Ewa	83.5	Makaweli	86.8	Ewa	82.6
Ewa	79.4	Makaweli	83.3	Ewa	86.5	Waipahu	82.1
Waipahu	79.1	Waipahu	82.9	Waipahu	85.8	Kealia	81.9
Eleele	78.6	Waimanalo	81.9	Waimanalo	85.2	Olaa	81.8
Kealia	78.6	Kealia	81.5	Kealia	84.9	Pahala	81.4
Waialua	78.5	Olaa	81.5	Wailuku	84.5	Wailuku	81.4
Waimanalo	78.4	Wailuku	81.4	Kahuku	84.1	Waialua	81.3
Pahala	78.4	Eleele	81.3	Pahala	83.9	Waimanalo	81.3
Kahuku	78.2	Pahala	80.8	Eleele	83.8	Lihue	81.2
Wailuku	78.1	Kahuku	80.7	Lihue	83.7	Eleele	81.1
Hana	78.0	Lihue	80.3	Olaa	83.4	Hana	80.8
Honokaa	77.8	Honokaa	80.3	Kilauea	82.8	Kahuku	80.5
Pepeekeo	77.7	Koloa	79.8	Koloa	82.6	Pepeekeo	80.5
Hilo	77.5	Hana	79.8	Honokaa	82.6	Ookala	80.3
Ookala	77.5	Kilauea	79.7	Hana	82.5	Honokaa	80.2
Kohala	77.3	Hilo	79.7	Hilo	82.0	Hilo	80.1
Lihue	77.2	Ookala	79.5	Ookala	82.0	Kohala	79.9
Koloa	77.0	Kohala	79.4	Pepeekeo	81.7	Koloa	79.7
Kilauea	76.9	Pepeekeo	79.2	Kohala	81.7	Kilauea	79.4
Hakalau	76.3	Hakalau	78.8	Hakalau	81.1	Hakalau	79.2
Cuba (Camaguey)	83.5	Cuba (Camaguey)	89.0	Cuba (Camaguey)	90.5	Cuba (Camaguey)	84.5
Java (Pasoeroean)	87.5	Java (Pasoeroean)	90.0	Java (Pasoeroean)	88.0	Java (Pasoeroean)	88.0

TABLE B-II

Seasonal Mean Minimum Temperatures—Plantations Arranged in Descending Order of Temperature

Station	Winter Temperature	Station	Spring Temperature	Station	Summer Temperature	Station	Fall Temperature
Hawaiian Islands							
Waimanalo	65.0	Waimanalo	68.9	Waimanalo	72.8	Waimanalo	68.9
Hana	64.6	Kahuku	68.4	Kealia	71.6	Kahuku	68.2
Kahuku	64.0	Kealia	68.0	Kahuku	71.5	Hana	67.9
Pepeekeo	63.3	Hana	67.6	Wailuku	70.8	Kealia	67.5
Wailuku	63.1	Puunene	67.5	Koloa	70.5	Wailuku	67.2
Hakalau	62.9	Wailuku	67.3	Puunene	70.3	Puunene	66.6
Kealia	62.8	Koloa	66.9	Waianae	70.0	Waianae	66.4
Waianae	62.7	Waianae	66.7	Eleele	69.9	Eleele	66.4
Makaweli	62.6	Eleele	66.5	Makaweli	69.8	Koloa	66.4
Hilo	62.6	Makaweli	66.4	Lihue	69.7	Makaweli	66.4
Ookala	62.6	Kaanapali	66.4	Hana	69.6	Pepeekeo	66.1
Puunene	62.5	Lihue	66.2	Kilauea	69.4	Hakalau	66.1
Kohala	62.5	Kilauea	66.0	Waipahu	69.2	Waipahu	65.9
Eleele	62.3	Waipahu	66.0	Kaanapali	68.8	Kilauea	65.9
Waipahu	62.3	Hakalau	65.8	Kohala	68.6	Kohala	65.8
Kaanapali	62.2	Pepeekeo	65.5	Pepeekeo	68.2	Ookala	65.7
Koloa	62.1	Kohala	65.5	Hakalau	68.2	Kaanapali	65.6
Kilauea	61.9	Hilo	65.3	Ewa	68.1	Hilo	65.5
Honokaa	61.2	Ewa	64.8	Hilo	67.7	Lihue	65.2
Ewa	61.0	Ookala	64.7	Ookala	67.2	Ewa	64.6
Lihue	60.7	Honokaa	64.2	Honokaa	66.7	Honokaa	64.2
Waialua	60.5	Waialua	64.0	Waialua	66.7	Waialua	63.8
Olaa	60.3	Olaa	62.3	Pahala	63.5	Olaa	63.4
Pahala	58.8	Pahala	61.3	Olaa	62.3	Pahala	62.4
Java (Pasoeroean)	69.4	Java (Pasoeroean)	72.3	Java (Pasoeroean)	73.8	Java (Pasoeroean)	72.8
Cuba (Camaguey)	63.9	Cuba (Camaguey)	69.6	Cuba (Camaguey)	74.6	Cuba (Camaguey)	68.6

TABLE C

Annual Mean Maximum Temperature of Hawaiian Plantations Compared to the Temperature of Pasoeroean, Java

Station	Annual Mean Temperature	Active Temperature*	Per Cent of Java Temperature
Java (Pasoeroean)	88.3	23.3	100
Cuba (Camaguey)	86.8	21.8	93
Hawaiian Islands			
Waianae	85.2	20.2	87
Kaanapali	84.8	19.8	85
Makaweli	83.2	18.2	78
Ewa	83.0	18.0	77
Puunene	82.9	17.9	77
Waialua	82.6	17.6	76
Waipahu	82.5	17.5	75
Olaa	81.8	16.8	72
Kealia	81.7	16.7	72
Waimanalo	81.7	16.7	72
Wailuku	81.4	16.4	71
Eleele	81.2	16.2	70
Pahala	81.1	16.1	69
Kahuku	80.9	15.9	68
Lihue	80.6	15.6	67
Hana	80.3	15.3	66
Honokaa	80.2	15.2	65
Koloa	79.8	14.8	63
Hilo	79.8	14.8	63
Pepeekeo	79.8	14.8	63
Ookala	79.8	14.8	63
Kilauea	79.7	14.7	63
Kohala	79.6	14.6	62
Hakalau	78.9	13.9	60

* "Active" temperature is equal to the number of degrees above 65° F.

TABLE D-I

Average Mean Maximum Temperature by Months

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Oahu—													
Ewa	78.6	79.6	79.9	81.6	83.7	85.3	86.2	86.8	86.6	85.2	82.5	80.2	83.0
Kahuku	77.8	78.7	78.1	78.9	80.7	82.5	83.7	84.0	84.6	83.8	81.2	79.6	81.1
Waialua	77.7	78.5	79.3	81.1	83.8	85.9	87.1	87.2	86.4	84.2	81.0	78.8	82.6
Waianae	80.1	81.2	82.0	83.5	85.5	87.1	88.8	89.4	88.7	87.4	85.1	83.0	85.2
Waimanalo	77.6	78.6	78.9	79.6	82.3	83.9	84.9	85.4	85.4	84.3	81.3	78.6	81.8
Waipahu	78.1	79.3	79.9	80.9	83.2	84.5	85.4	86.0	86.0	84.6	82.1	79.7	82.5
Maui—													
Hana	77.8	78.4	77.8	78.2	80.1	81.2	82.0	82.4	83.1	82.5	80.6	79.2	80.3
Kaanapali	79.9	80.7	81.3	82.3	85.6	87.2	88.3	89.2	88.9	87.6	84.5	81.6	84.8
Puunene	78.0	79.6	80.0	81.4	84.1	85.3	86.1	86.1	86.1	85.1	82.7	79.9	82.9
Wailuku	77.6	78.3	78.5	79.5	81.6	83.1	83.9	84.7	85.0	83.9	81.3	78.9	81.4
Kauai—													
Eleele	77.8	79.0	79.1	79.6	81.7	82.6	82.9	84.4	84.0	83.5	81.0	78.8	81.2
Kealia	78.2	78.8	78.7	79.8	81.6	83.1	84.3	85.0	85.3	84.1	81.8	79.8	81.7
Kilauea	76.4	77.4	76.8	77.8	79.9	81.5	82.4	82.9	83.0	81.7	79.1	77.3	79.7
Koloa	76.2	77.4	77.5	78.3	80.0	81.2	81.9	82.7	83.2	82.2	79.5	77.3	79.8
Lihue	76.9	77.3	77.5	78.3	80.4	82.2	83.3	83.9	84.0	82.6	79.8	78.1	80.4
Makaweli	78.7	79.8	80.0	81.4	83.4	85.1	86.4	87.2	86.7	85.4	82.7	80.7	83.1
Hawaii—													
Hakalau	76.1	76.5	76.2	77.3	79.1	80.0	80.7	81.3	81.4	80.8	79.1	77.7	78.9
Hilo	77.3	77.7	77.5	78.1	80.0	80.9	81.8	82.2	82.3	81.7	80.1	78.6	79.8
Honokaa	77.2	77.9	78.2	78.6	80.4	82.3	82.0	82.7	83.1	82.3	80.2	78.0	80.2
Kohala	77.2	77.3	77.4	77.7	79.5	80.7	81.2	81.7	82.1	81.8	79.8	78.0	79.5
Olaa	79.8	81.1	80.9	80.4	81.6	82.7	83.2	83.4	83.7	83.4	81.6	80.4	81.8
Ookala	77.3	77.4	77.7	77.9	79.5	81.2	81.6	82.1	82.2	82.0	80.3	78.6	79.8
Pahala	78.2	78.6	78.6	79.7	80.7	81.9	83.7	84.0	84.0	83.0	81.4	79.8	81.1
Pepeekeo	77.5	78.0	77.6	77.9	79.4	80.2	81.3	81.9	81.8	82.0	80.6	78.9	79.8
Java (Pasoeroean)	87.6	87.6	87.8	88.3	88.3	87.8	87.2	87.8	89.2	90.3	89.8	88.5	88.3

TABLE D-II

Average Mean Minimum Temperature by Months

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Oahu—													
Ewa	60.9	60.4	61.6	63.3	64.7	66.5	67.9	68.6	67.9	66.5	64.5	62.8	64.6
Kahuku	63.9	63.4	64.8	66.8	68.3	70.2	71.0	71.9	71.6	70.2	68.1	66.2	68.0
Waialua	60.7	60.0	60.8	62.6	63.9	65.4	66.6	67.0	66.4	65.4	63.9	62.1	63.7
Waianae	62.4	62.0	63.6	65.3	66.7	68.0	69.8	70.2	70.0	68.6	66.4	64.2	66.5
Waimanalo	64.4	64.6	66.0	67.4	69.6	69.6	72.5	73.0	72.8	71.1	69.1	66.8	68.9
Waipahu	62.3	61.7	63.0	64.5	65.8	67.7	69.0	69.6	68.9	67.7	66.0	64.1	65.9
Maui—													
Hana	64.5	64.5	64.9	66.3	67.5	69.6	70.1	70.2	68.6	69.5	67.9	66.4	67.5
Kaanapali	62.2	66.5	63.0	64.4	66.6	68.2	68.5	69.0	68.8	67.5	65.7	63.7	65.8
Puunene	62.6	61.4	63.5	65.9	67.6	69.1	70.2	70.7	70.1	68.4	66.7	64.8	66.8
Wailuku	63.0	62.6	63.7	65.5	67.3	69.1	70.5	71.2	71.0	69.3	67.0	65.2	67.1
Kauai—													
Eleele	62.0	62.3	62.7	64.2	66.9	68.5	69.8	70.0	69.8	68.6	66.7	64.0	66.3
Kealia	62.5	62.1	63.7	65.9	67.9	70.2	71.4	72.0	71.5	70.0	67.4	65.1	67.5
Kilauea	61.7	61.5	62.5	64.4	65.7	68.0	69.0	69.9	69.2	68.0	65.9	63.8	65.8
Koloa	61.7	61.7	62.8	64.8	66.8	69.1	70.2	70.9	70.4	68.8	66.3	64.2	66.5
Lihue	60.6	60.1	62.0	64.0	66.1	68.4	69.5	70.1	69.6	67.5	65.0	63.1	65.5
Makaweli	62.3	62.4	63.1	64.4	66.4	68.4	69.6	70.0	69.7	68.4	66.4	64.3	66.3
Hawaii—													
Hakalau	63.0	62.6	63.2	64.5	66.2	66.9	68.0	68.6	68.0	67.6	66.1	64.6	65.8
Hilo	62.5	62.2	63.0	64.2	65.2	66.4	67.4	68.1	67.5	66.9	65.7	64.0	65.3
Honokaa	61.0	60.8	61.8	62.7	64.5	65.7	66.2	67.3	66.7	65.8	64.1	62.6	64.1
Kohala	62.2	62.3	63.0	63.9	65.4	67.1	68.1	68.7	68.9	67.4	65.7	64.3	65.6
Olaa	60.2	59.9	60.9	62.2	63.1	64.3	65.3	65.9	65.6	64.8	63.3	62.2	63.1
Ookala	62.7	62.3	62.9	63.6	64.8	65.8	66.4	67.2	68.0	67.0	65.8	64.4	65.1
Pahala	58.8	58.5	59.2	60.4	61.3	62.1	63.1	63.5	63.8	63.2	62.0	60.8	61.4
Pepeekeo	63.2	63.1	63.5	64.8	65.8	66.5	67.8	68.4	68.4	67.4	66.3	64.7	65.8
Java (Pasoeroean)	73.8	73.8	73.6	72.7	72.0	70.5	68.7	69.1	70.5	72.5	73.8	73.8	72.1

TABLE E

TEMPERATURE DEPARTURES FROM THE AVERAGE BY MONTHS

MEAN MAXIMUM TEMPERATURE

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MAXIMUM TEMPERATURE

Station: Hakalau

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—2.7	—2.2	— .6	—1.0	....	— .1	+ .3	— .5	....	—1.3	—1.5	—1.0
1906....	+2.2	+3.3	+2.1	+3.7	+2.6	+2.8	+ .8	....	....	....	....	....
1907....	+5.2	+3.4	+2.2	+1.8	+3.9	+2.9	+3.4	+1.0	+3.0	+2.1	+2.7	+2.6
1908....	+2.1	+ .9	+1.8	+1.0	+ .7	+ .4	+ .5	+2.1	+ .8	—1.2	+1.6	—1.5
1909....	+1.5	0	—1.6	+ .5	+ .9	+1.5	+ .4	+1.2	+1.3	+1.2	+2.3	+ .9
1910....	—1.3	— .1	+ .6	— .5	+ .4	— .4	+1.1	+1.4	+2.6	+1.7	+1.6	+ .9
1911....	0	— .1	+ .5	— .6	— .5	—1.5	—1.1	+ .3	—2.3	—1.4	— .8	+ .2
1912....	+1.7	— .3	—2.7	—1.0	— .7	—1.4	— .5	+ .9	+ .5	—1.9	—1.1	+ .1
1913....	—1.0	+ .4	+2.1	+1.0	— .4	— .2	+ .2	+1.0	— .4	— .3	—3.7	—5.8
1914....	—7.5	—4.0	—1.5	+1.6	— .5	+ .5	+1.2	+2.2	+ .3	+2.1	+2.1	—2.0
1915....	—1.4	—1.9	+ .9	— .2	+2.4	+2.3	+ .9	+1.7	+1.9	+ .3	—2.0	+ .3
1916....	+ .6	+3.6	+2.5	+1.5	— .2	—1.2	—1.3	—1.8	—1.0	0	+ .8	— .5
1917....	— .3	+ .7	— .6	+1.0	0	+ .4	+ .6	+1.0	+1.7	+1.8	+2.0	+1.6
1918....	+1.4	— .7	—1.0	—1.5	—1.3	+ .2	— .3	+ .5	+ .7	— .4	—1.0	—2.1
1919....	—2.3	—1.5	—3.0	+ .6	— .7	—1.0	— .1	—1.4	+ .6	— .7	—1.4	— .3
1920....	+1.3	+1.0	+ .4	— .4	+1.7	—1.2	—1.1	— .6	—1.0	+ .2	0	— .2
1921....	—1.6	+ .4	+ .2	+2.5	+5.0	+4.5	+3.3	+1.5	+1.0	+2.9	+3.5	+1.5
1922....	+1.9	—2.8	—2.5	—1.4	—2.8	—2.0	—1.1	—1.9	—2.4	—1.0	—2.0	+ .6
1923....	—2.0	—2.2	—2.2	—1.7	—2.0	—2.5	—2.3	—1.2	— .5	— .4	—1.1	—1.5
1924....	— .9	— .2	—1.5	— .9	—2.0	—1.0	—2.2	—2.1	—1.2	+ .3	— .9	+2.0
1925....	+ .7	+1.1	+ .4	—1.8	—2.7	—1.8	—1.1	—1.5	—1.4	+ .1	+1.1	+3.9
1926....	+2.7	+1.7	+2.3	—1.1	+ .7	+ .9	0	— .6	+1.2	+ .1	—1.2	+ .8
1927....	+ .7	+2.4	+1.8	+1.3	— .6	— .4	—1.0	—1.4	—1.1	— .8	+ .7	+1.1
1928....	— .2	—3.2	+ .3	— .1	—1.6	— .9	—1.8	—1.2	—2.7	—2.3	—1.3	—1.9
1929....	—1.8	—2.8	—1.4	— .9	— .9	— .5	+1.5	— .1	0	0	— .6	— .6
1930....	+ .2	+2.1	—1.3	—2.9	—1.5	—1.5	— .2	—1.0	—1.1	— .3	....	....
Means ..	76.1	76.5	76.2	77.3	79.1	80.0	80.7	81.3	81.4	80.8	79.1	77.7

Station: Hilo

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	+ .3	— .3	+2.4	+1.3	+ .6	—2.6	—2.1	—1.5	—2.5	....	— .8	0
1906....	+1.9	+1.7	+ .4	+1.8	+ .3	+1.4	+ .7	+ .9	+1.2	+2.3	+1.6	+1.2
1907....	+2.5	+ .6	—1.5	— .2	+1.9	+2.7	+1.7	— .5	+1.3	+ .7	+1.5	+1.7
1908....	+ .2	—1.5	+ .8	—1.8	—1.7	—2.1	—2.1	— .9	—1.2	—1.6	+ .3	—3.5
1909....	+ .4	—1.7	—2.5	+ .6	—1.4	— .1	+ .2	— .4	— .6	— .1	+ .4	+1.6
1910....	+ .2	— .9	— .6	—2.3	—2.3	—2.4	—1.2	+1.7	+1.6	....	....	— .6
1911....	—2.3	—2.6	—1.1	—1.8	—2.0	—2.3	—1.5	— .9	+1.5	—1.9	—2.0	—1.7
1912....	— .6	+1.6	—4.2	—2.2	—2.3	—2.0	—1.5	+ .4	—1.4	—1.2	—1.2	— .6
1913....	—1.3	— .3	— .1	—1.1	—1.1	—1.6	—1.9	— .2	—3.1	—4.5	—5.6	—1.2
1914....	—2.5	+ .9	+ .6	— .1	—2.5	—3.5	—4.2	—1.7	—1.7	+ .2	+1.1	—3.0
1915....	—1.4	—3.6	+ .6	— .2	+ .6	+ .2	— .3	+ .6	+1.2	—1.7	—1.8	+ .6
1916....	+ .1	—4.9	— .1	+ .9	+ .8	—1.1	— .6	—1.5	+ .5	0	+ .2	—1.7
1917....	+ .1	+1.5	—2.0	—3.2	+4.2	+2.0	+ .6	+1.4	— .4	+2.9	+2.3	+4.6
1918....	+3.4	+2.3	+ .3	+ .8	—1.1	+ .1	0	+2.1	+4.0	+2.4	+1.9	— .4
1919....	+ .3	+ .5	+ .7	+2.0	+ .5	+1.3	+ .6	— .4	+ .4	+ .3	+1.2	+2.5
1920....	+2.8	+2.1	+1.0	+1.4	+4.7	+4.2	+3.0	+2.3	— .2	0	+ .6	+ .5
1921....	—1.4	+4.1	+2.5	+3.9	+1.8	+2.2	+ .7	+ .3	— .5	+ .8	— .8	— .5
1922....	—1.5	—1.7	—1.1	+ .3	— .5	+ .8	+2.3	+ .7	+ .8	+1.2	+ .1	+2.4
1923....	—1.2	+ .1	— .2	+ .5	+ .9	— .1	+ .1	+1.1	+1.2	+ .8	— .2	—1.6
1924....	— .9	+ .4	— .3	+ .1	— .8	+ .2	—1.2	+1.5	— .1	—1.2	+ .2	+2.2
1925....	+ .9	+2.4	— .4	—1.5	—1.5	+ .1	+ .5	— .7	—1.2	— .2	— .2	+2.0
1926....	+3.0	+2.1	+1.3	+ .9	+1.0	+2.0	+1.3	+ .2	+1.4	+ .9	+2.2	+1.2
1927....	+ .9	+3.0	+ .3	+1.3	+ .2	+ .8	— .6	—2.1	— .5	— .6	+ .1	—1.8
1928....	—1.1	—3.4	+2.2	+1.0	— .5	+ .2	—1.2	—1.0	—1.6	— .8	—1.6	—2.4
1929....	— .8	—2.0	+ .1	+ .5	+1.3	+ .3	— .1	+ .3	+ .8	— .5	—2.2	—3.1
1930....	—2.2	0	+ .3	—2.2	+ .1	+ .4	+ .9	+1.0	+1.6	+1.5	+2.0	+2.3
Means..	77.3	77.7	77.5	78.1	80.0	80.9	81.8	82.2	82.3	81.7	80.1	78.6

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MAXIMUM TEMPERATURE

Station: Honokaa Mill

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—3.8	—2.2	—2.6	—2.7	—1.9	—1.7	— .7	— .8	—1.2	—1.3	—1.4	—1.1
1906....	+1.2	+1.0	0	+1.3	— .5	+ .5	+1.0	+ .5	+1.1	+2.0	+2.2	—2.1
1907....	+1.2	—1.7	—5.1	— .9	+3.9	+1.4	+1.6	—1.0	— .8	—3.3	—2.3	— .9
1908....	—1.5	+ .1	+2.2	— .4	— .9	—2.3	—3.6	—3.1	—2.4	—2.7	—1.1	—2.8
1909....	— .5	—2.1	—2.8	— .2	— .6	— .2	— .9	+ .1	+1.0	— .1	+1.1	+1.3
1910....	—1.7	— .8	+ .4	— .6	— .7	—3.1	—2.1	—1.1	+1.0	—1.1	0	—2.0
1911....	—2.0	—1.9	+ .9	+1.3	+ .8	— .6	— .1	+ .6	—3.8	—2.6	—2.5	—3.0
1912....	— .5	—2.2	—3.8	—2.4	—1.7	—2.0	— .6	— .4	—1.0	— .5	— .6	— .5
1913....	+ .3	+ .5	+1.7	— .8	+ .2	+2.7	+4.0	+4.0	+2.8	+3.1	— .2	—1.2
1914....	—2.4	— .3	— .2	0	—2.7	— .9	+ .1	— .9	— .7	—1.3	— .9	—3.3
1915....	—1.5	—6.9	—2.0	—2.7	—4.5	+ .8	— .8	+ .4	— .5	—2.7	—2.8	— .6
1916....	— .6	+ .8	—2.0	—1.9	—2.9	—3.5	—2.6	—3.5	—2.7	—2.2	—2.6	—2.4
1917....	— .8	—1.0	—1.5	— .8	+ .4	— .9	+ .3	+ .9	+ .9	+ .4	— .3	— .1
1918....	+ .7	—2.5	—2.9	—4.7	—3.4	+ .1	—1.1	+ .3	— .8	—2.1	—1.4	—2.7
1919....	—2.0	—1.0	—2.8	—1.3	—1.7	—1.0	—1.6	—2.1	— .8	— .9	— .3	0
1920....	— .3	+3.0	+2.0	+3.6	+6.0	+3.9	+2.9	+1.0	+ .5	+2.2	+1.0	+ .6
1921....	+1.1	+3.6	+2.4	+2.0	+2.8	+2.7	+3.0	+2.4	+2.4	+2.0	+3.0	+5.1
1922....	+3.8	+2.6	+4.0	+6.3	+4.8	+1.9	— .5	— .2	+ .9	+3.3	+1.6	+3.5
1923....	+3.8	+3.4	+4.4	+5.6	+3.4	+2.7	+3.3	+2.7	+1.5	+2.7	+3.4	+1.4
1924....	— .7	— .6	— .4	0	— .1	+ .3	+ .1	+ .2	+1.4	—1.0	+1.0	+3.9
1925....	+ .9	+1.1	+1.9	+ .2	+ .7	— .5	+1.5	+ .2	+ .5	+1.8	+1.4	+6.2
1926....	+4.8	+1.9	+2.8	+ .1	+ .9	+2.2	+2.2	+1.1	+2.8	+3.7	+2.9	+3.5
1927....	+1.7	+4.3	+2.2	+1.7	+1.7	+1.9	+ .7	+ .7	+1.4	+2.1	+2.8	+1.5
1928....	0	+ .5	+3.3	+2.5	+ .7	—1.3	—3.9	— .9	—1.8	0	—1.6	—2.1
1929....	—1.4	—2.1	— .2	— .6	—1.1	— .6	+ .0	+ .5	+1.1	+ .7	0	—1.8
1930....	— .1	+1.6	—1.7	—4.2	—2.5	—3.4	—2.9	—2.8	—1.8	—1.7	—2.3	—2.8
Means..	77.2	77.9	78.2	78.6	80.4	82.0	82.3	82.7	83.1	82.3	80.2	78.0

Station: Kohala Mill

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— .5	+ .6	— .1	— .8	— .9	+ .7	+ .4	— .2	— .9	—1.0	— .4	— .5
1906....	+ .7	+1.2	+ .7	+ .7	—1.2	— .7	— .8	—1.0	+ .5	+1.3	+2.1	— .3
1907....	+2.5	+ .4	—1.3	— .8	+2.5	+1.5	+ .4	—1.4	— .1	—1.1	— .7	+ .8
1908....	— .3	— .5	+1.9	— .8	—1.3	—2.4	—2.6	—2.0	—2.0	—2.7	— .8	—3.3
1909....	— .7	—1.8	—3.2	— .2	— .6	— .2	—1.8	0	+ .4	— .3	+ .6	+ .6
1910....	—2.2	—1.3	—1.4	—2.0	—1.4	—2.6	—1.8	—1.4	+1.5	—1.2	— .2	—1.3
1911....	—3.2	—2.9	—1.0	—1.0	—1.0	—3.2	—1.4	— .3	—2.4	—1.4	—2.6	—1.9
1912....	+ .7	— .7	—3.4	—2.5	—2.0	—2.2	—1.2	+ .7	— .1	—1.2	—1.9	—1.3
1913....	+ .2	— .3	+ .1	—1.1	—1.8	— .9	— .8	+ .6	+1.3	+4.6	+ .1	—1.0
1914....	—2.4	+1.6	+ .6	+ .4	—2.5	—3.0	—2.2	—2.6	—2.0	—2.3	—1.0	—1.1
1915....	—2.1	—4.5	+ .9	— .1	+1.2	+1.8	+ .8	+1.8	+1.3	—1.3	—1.8	— .2
1916....	— .5	+2.0	+ .3	+ .7	—1.2	—2.6	—2.2	—2.8	—2.3	—1.5	—1.5	—1.9
1917....	— .3	+1.6	— .7	+ .9	+ .7	+ .2	+1.4	+2.1	+2.2	+1.9	+ .5	+1.9
1918....	+ .5	—2.1	—2.6	—2.4	—1.8	— .2	—1.3	— .1	+ .3	0	+1.3	—1.1
1919....	+ .1	— .1	+ .7	+1.7	+1.5	+1.7	+1.0	+ .8	+1.2	+1.7	+2.7	+2.6
1920....	+2.8	+1.7	+1.1	+1.5	+3.4	+2.2	+2.4	+1.8	+ .2	+ .1	+ .8	+1.7
1921....	0	+2.0	+1.9	+ .8	+3.6	+4.9	+4.4	+4.9	+1.6	+ .6	—1.0	+2.2
1922....	+1.1	—2.1	—1.2	+ .9	+ .1	+1.8	+2.3	— .7	—1.6	—1.0	— .9	+ .8
1923....	—1.9	+ .1	— .2	— .2	— .4	—1.2	—1.2	+ .5	+ .5	0	—1.3	—1.3
1924....	+1.6	+ .9	+1.1	+2.1	+1.0	+ .2	— .5	—1.2	— .4	—1.6	0	+2.0
1925....	— .1	+ .9	— .1	—1.9	—1.5	—2.0	+ .5	— .6	+ .3	+1.0	0	+4.3
1926....	+2.5	+ .1	+ .9	—1.2	— .1	+2.1	+1.6	+ .6	+1.2	+2.4	+2.0	+2.5
1927....	+ .8	+3.3	—6.6	+1.1	+ .7	+1.1	— .4	— .9	+1.2	+ .6	+1.7	+ .7
1928....	— .2	0	+3.3	+3.4	— .1	— .1	— .7	+ .2	— .5	—1.1	—1.7	—4.5
1929....	— .8	—2.9	+ .7	+2.0	+3.5	+4.2	+3.2	+1.5	+3.1	+1.6	+2.6	— .1
1930....	+1.9	+2.9	+ .2	—1.8	— .6	—1.3	— .6	—1.2	—3.8	+ .9	+1.0	+ .8
Means..	77.2	77.3	77.4	77.7	79.5	80.7	81.2	81.7	82.1	81.8	79.8	78.0

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MAXIMUM TEMPERATURE

Station: Olaa Mill

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— .1	—2.2	+3.5	+3.0	+ .2	+5.1	+4.2	+6.3	+6.3	+5.6	+5.4	+8.8
1906....	0	+4.2	+5.8	— .1	— .3	+1.9	0	+1.0	— .3	+3.7	+4.1	+4.4
1907....	+6.5	+4.1	+2.2	+2.5	+3.1	+6.3	+4.3	+ .5	+3.8	+4.0	+4.1	+5.4
1908....	+ .9	—2.7	+ .7	—1.9	—1.6	—2.2	—2.4	—2.4	—2.7	—2.4	—1.5	—4.2
1909....	—2.6	—3.8	—2.9	+ .5	—2.1	— .8	—1.8	—2.1	—2.4	—1.7	— .8	—1.4
1910....	—4.4	—5.2	—4.1	—4.6	—2.6	—3.8	—2.1	—2.9	—1.6	—3.1	—1.5	+ .6
1911....	+1.3	—4.3	—1.2	— .6	—1.4	—2.7	— .3	+1.0	+ .6	+1.1	+3.1	— .9
1912....	+3.1	+6.6	+3.4	+3.5	+ .8	— .2	+ .5	+2.1	+1.1	+1.8	+ .1	+ .8
1913....	+ .7	+2.0	+1.8	+1.4	+3.0	+1.0	+1.1	+2.9	+1.7	+2.3	+ .1	+1.4
1914....	— .6	+ .1	+1.3	+1.1	—1.0	—2.3	—1.3	— .8	—1.4	— .6	+ .7	—1.1
1915....	0	—4.2	+1.2	+ .7	+3.0	+1.2	+1.2	+ .8	+ .7	—2.0	—2.4	— .4
1916....	+ .1	+ .9	+ .1	+1.1	— .7	—3.3	—2.5	—3.3	—2.3	—1.6	—1.7	—1.9
1917....	—1.4	+1.6	—1.6	— .3	+ .1	—1.1	+ .7	+ .1	+1.1	+ .6	— .3	+2.3
1918....	+1.5	—1.6	—4.0	— .9	+ .5	— .5	—1.5	— .9	—1.1	—1.0	— .3	—1.7
1919....	—2.2	—2.5	—2.3	+ .9	— .1	+ .3	+ .6	+ .4	0	— .4	— .7	+2.5
1920....	+2.7	+ .7	—1.1	+1.5	+4.0	+2.4	+2.1	+ .9	+ .3	—1.1	— .9	— .3
1921....	—2.0	+1.4	+3.3	+1.2	+2.5	+2.4	+3.3	+ .8	+ .2	+2.1	+ .3	— .3
1922....	0	— .4	+1.0	+ .8	+ .6	+1.1	+2.6	+1.9	+2.6	+3.7	+3.0	+4.3
1923....	+2.3	+3.8	—3.3	—7.0	—2.1	—7.1	—7.1	—4.6	—4.8	—6.4	—7.5	—7.4
1924....	—3.4	— .3	—1.9	+1.2	+ .9	+1.9	+ .1	+1.3	+ .8	+ .4	+2.3	+3.7
1925....	+1.9	+3.8	+1.2	— .1	+ .3	+2.1	+1.9	+1.1	+1.1	+1.2	+ .5	+4.8
1926....	+3.0	+2.4	+2.3	+1.5	+2.8	+4.3	+4.3	+1.5	+1.6	+2.5	+ .6	—1.2
1927....	—1.3	+1.6	— .9	+ .7	— .5	+ .7	— .7	—1.9	—1.0	—2.0	— .3	—3.8
1928....	—2.9	—3.4	+1.9	— .1	— .5	— .2	—1.6	— .1	— .9	—2.1	—1.5	—3.7
1929....	—2.6	—3.9	—3.6	—2.0	— .3	— .1	+ .3	+ .2	+ .8	— .7	— .4	—1.9
1930....	— .7	+1.0	—2.2	—4.4	+1.8	—5.6	—5.7	—4.5	—3.4	—3.9	—4.3	—7.7
Means..	79.8	81.1	80.9	80.4	81.5	82.7	83.2	83.4	83.7	83.4	81.6	80.4

Station: Ookala

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—1.6	—1.9	—2.1	—2.5	—1.3	—2.1	—1.2	—2.0	—3.5	—2.4	....	—1.7
1906....	0	+ .9	—1.7	— .2	—2.6	+ .1	+ .3	—1.3	— .7	+ .4	+ .8	+ .1
1907....	+2.4	— .6	—2.5	—2.9	— .2	— .4	— .6	—1.0	+2.2	+ .6	+ .1	— .5
1908....	—1.8	—1.7	+1.2	—2.3	—2.6	—2.9	—2.5	—2.5	—1.9	—1.8	— .3	—3.8
1909....	+1.0	+1.1	—1.5	+1.9	+ .9	+ .4	—1.8	+ .4	+1.9	— .2	+ .2	— .5
1910....	....	—2.0	—1.2	— .5	—2.6	....	....	....	....	....	....	+6.8
1911....	+5.0	+3.5	+4.1	—1.5	—2.8	—3.8	—3.0	—1.4	—3.5	—3.6	—2.9	—3.3
1912....	—1.0	—1.4	—3.7	....	—1.0	—1.0	— .4	0	— .1	—1.6	—3.0	—2.8
1913....	—2.8	—1.6	—1.0	—1.2	—1.0	— .9	— .2	+ .7	+ .3	+ .4	—2.9	—2.4
1914....	—3.7	—1.3	—1.6	—1.4	—2.9	—3.1	—2.7	—2.3	—2.6	—2.5	—2.1	—2.7
1915....	—2.9	—4.9	—1.5	—1.9	+ .1	0	— .6	+1.2	+ .9	—2.0	—1.9	— .4
1916....	+1.0	+1.5	+ .6	+ .1	— .7	—2.5	—2.7	—2.9	—2.0	— .5	+ .1	+3.5
1917....	+3.3	+2.1	+ .2	+ .7	+ .7	0	+1.1	+2.8	+3.3	+2.3	+ .5	+2.3
1918....	+2.2	+ .3	—1.5	—1.7	—1.6	— .2	— .8	— .4	+ .9	+ .5	— .6	—2.0
1919....	— .2	—1.3	—1.0	0	— .3	+1.0	+1.6	+1.1	—4.1	—2.5	— .7	+1.0
1920....	—1.7	—1.8	+1.7	+2.0	+3.1	+3.2	+3.2	+2.1	+ .9	— .8	— .1	—1.2
1921....	—2.9	+1.1	+1.1	+ .1	+ .7	+1.3	+ .4	—1.3	—1.7	— .6	+1.1	+1.5
1922....	+1.8	— .5	+2.0	+3.5	+2.5	+ .6	+ .9	+1.1	+1.1	+1.2	+1.6	+2.2
1923....	—1.3	+1.6	+2.0	+ .7	—1.0	—2.1	—2.7	—1.3	— .4	+ .9	+1.1	— .8
1924....	—1.0	— .9	—1.3	+ .9	+1.8	+1.9	+1.7	— .3	+ .9	— .2	+1.7	+3.6
1925....	+2.1	+2.9	+2.0	+ .7	+ .2	+ .5	+ .9	+ .8	+ .3	+1.2	0	+1.8
1926....	—2.9	+1.7	+2.4	+ .2	+1.6	+3.6	+3.5	+2.4	+3.0	+2.1	+1.0	+2.0
1927....	— .1	+3.8	+1.7	+ .6	+2.9	+1.5	+1.1	+ .2	+1.5	+2.1	+1.7	— .3
1928....	+2.3	+2.1	+3.7	+5.0	+4.5	+3.4	+ .5	+ .8	— .1	— .5	— .4	—1.9
1929....	—1.6	—4.9	—1.0	+ .5	+1.0	+1.9	+2.5	+3.3	+4.3	+3.5	+2.5	—2.2
1930....	—1.8	+1.0	— .6	—2.0	0	— .9	+ .3	....	....	+3.2	+2.7	+2.1
Means..	77.3	[illegible]	77.7	77.9	79.5	81.2	81.6	82.1	82.2	82.0	80.3	78.6

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MAXIMUM TEMPERATURE

Station: Pahala

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— .4	+1.9	+2.0	+2.5	+3.1	+1.5	+2.0	+2.6	+2.2	+2.5	— .5	+ .1
1906....	+ .9	+ .7	+1.8	+2.4	+1.6	+1.3	+2.8	+ .1	+ .6	+2.7	+1.1	0
1907....	— .3	+ .1	—1.4	— .7	0	+ .9	+ .8	— .7	— .6	— .4	+1.0	+1.8
1908....	+1.4	— .8	—1.6	—1.4	—1.5	— .4	+ .2	+1.1	+ .7	— .5	+1.6	+2.2
1909....	+2.6	+1.0	—1.0	—1.8	—1.7	— .1	— .2	— .3	— .4	— .2	+ .1	— .3
1910....	— .6	— .1	— .3	— .7	0	+ .5	— .6	— .5	—1.9	— .5	+ .2	+ .6
1911....	— .5	—1.1	—1.2	— .8	+1.2	+ .2	+ .7	+1.9	+1.4	+ .5	+1.7	+3.6
1912....	+2.1	+3.0	— .4	+2.7	+1.8	+1.7	+1.2	+3.0	+3.8	+3.9	+4.5	+3.8
1913....	+1.0	+1.9	+2.2	+2.7	+ .8	— .7	0	+ .5	+ .8	+ .4	— .8	+ .3
1914....	+2.3	—1.2	—1.1	— .6	—1.5	— .8	—2.0	—1.9	—2.5	—1.1	—1.0	—1.7
1915....	— .7	—1.8	— .6	— .4	0	—1.1	—1.9	—1.6	— .3	—1.4	—2.4	—1.3
1916....	— .8	+1.0	—1.1	+ .8	+1.1	+1.2	— .8	—1.0	+ .8	— .6	—1.6	—1.9
1917....	—2.2	— .6	—1.4	—1.9	—2.7	—2.5	—2.2	—1.5	0	— .8	+1.3	— .5
1918....	+1.5	— .9	—1.0	—1.6	—1.1	—1.3	—1.2	—1.4	—1.8	— .8	— .1	+ .3
1919....	— .7	— .6	—1.3	—1.5	—1.0	—1.8	—1.2	— .2	—1.8	—2.0	—2.0	+ .4
1920....	+1.1	— .5	— .4	—1.9	—1.5	—2.0	—3.1	—3.1	—4.4	— .9	—2.9	—1.7
1921....	—4.7	—2.4	— .9	—2.8	—1.7	— .5	— .6	—1.1	—1.1	—1.1	— .8	—1.9
1922....	—1.5	—3.6	—1.0	—1.2	—2.4	—1.9	—1.8	—1.1	— .5	— .7	— .8	— .7
1923....	—2.6	—1.0	—1.2	—1.1	— .9	— .8	— .3	+ .4	— .3	+ .6	— .1	— .6
1924....	— .6	+ .3	0	— .9	— .9	— .6	—2.3	—3.1	....	— .8	+ .2	+ .3
1925....	+ .9	+1.8	+2.3	+1.6	+ .5	+3.3	+2.2	+3.3	+3.4	+2.9	+ .4	+1.9
1926....	+2.5	+2.4	+3.2	+2.6	+3.4	+3.3	+3.8	+2.7	+2.4	+2.4	+ .7	+1.1
1927....	+ .8	+3.7	+1.5	+2.6	+1.7	+2.2	+2.8	+1.7	+1.4	— .8	+ .4	—3.0
1928....	— .2	— .3	+1.8	+2.0	+2.1	+2.1	+ .8	+1.2	— .3	—1.2	— .8	— .7
1929....	+ .3	—2.2	— .2	— .6	+ .7	0	—1.1	+ .6	— .9	—1.7	—2.3	—1.7
1930....	—1.2	— .5	+ .1	—1.0	+ .1	—3.3	+1.8	—1.0	—1.9	+ .4	+2.2	+ .4
Means..	78.2	78.6	78.6	79.7	80.7	81.9	83.7	84.0	84.0	83.0	81.4	79.8

Station: Pepeekeo

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—2.1	—1.6	— .9	— .4	— .7	— .2	+ .8	+ .4	+1.3	— .4	— .8	+ .2
1906....	+1.3	+1.5	— .1	+1.1	+ .2	+1.1	+1.2	+ .7	+1.8	+1.8	+ .8	— .1
1907....	+1.1	+1.3	—1.5	— .1	+ .9	....	+1.9	0	+ .2	+ .2	+ .3	+ .3
1908....	+ .2	—1.7	— .1	— .8	+3.6	— .5	— .5	+ .7	+ .3	+ .5	+3.4	+1.6
1909....	+2.6	+ .8	+ .7	— .1	—1.2	— .3	—1.3	— .9	—1.0	— .7	0	+ .2
1910....	—2.0	— .6	— .1	—1.4	—1.2	—1.4	—1.0	— .7	+1.4	— .2	— .7	— .5
1911....	— .7	—2.8	+ .6	— .3	— .1	— .9	— .7	+ .4	— .6	+ .2	— .9	—1.0
1912....	+1.6	+ .7	—1.5	— .3	— .3	— .2	+ .1	+ .5	+1.4	+ .6	+1.0	— .6
1913....	+ .2	+2.3	+2.6	+1.5	+1.1	+1.8	+1.6	+1.3	+1.5	+1.7	— .8	+ .7
1914....	— .1	+ .2	+ .3	+ .4	—1.9	—2.5	—1.3	—1.5	—1.4	+ .2	+1.2	+ .3
1915....	+ .5	—2.5	+ .9	+ .8	+1.6	+1.8	+ .8	+1.3	+2.3	+ .2	—1.7	+ .8
1916....	+1.5	+2.8	+2.2	+1.2	+1.0	+1.1	....	+ .6	....	+1.3	0	— .1
1917....	0	+ .6	+ .3	+ .8	+ .3	0	+1.1	+1.4	—1.0	—3.7	—4.2	—4.4
1918....	—4.6	—6.4	—6.7	—5.5	—5.1	—1.4	—2.2	—2.2	—2.4	—2.0	—3.8	—4.3
1919....	—4.9	—2.9	—3.7	—2 6	—3.6	—2.9	—3.2	—4.6	—3.4	—4.5	—4.4	—3.6
1920....	—3.7	—3.2	—1.8	—2.3	— .9	—5.1	—5.1	—3.5	—2.4	—4.0	—4.6	—4.6
1921....	—4.8	+ .5	— .6	— .9	—1.3	— .5	—1.5	—3.3	—3.2	—2.7	+ .1	+ .5
1922....	+ .9	— .3	— .7	+ .5	— .9	— .2	+ .8	+ .8	+1.3	+1.1	— .4	+2.8
1923....	0	+ .6	— .6	— .1	+ .3	+ .1	+ .3	+1.1	+2.0	+1.9	+1.3	— .7
1924....	+1.6	+ .9	+ .8	+1.3	+ .9	+1.8	+ .8	+1.1	+2.3	+ .6	+2.5	+4.2
1925....	+3.6	+2.5	+1.1	+ .4	+ .8	+ .7	+ .5	+ .7	+1.8	+1.4	+1.7	+3.1
1926....	+4.3	+1.8	+4.3	+2.7	+2.2	+2.5	+1.8	+ .8	+ .5	0	+ .7	+ .1
1927....	— .2	+2.8	+ .2	+1.3	+ .4	+1.3	+ .2	—2.0	+ .2	— .4	+ .2	—1.4
1928....	+ .4	0	+2.5	+1.9	+1.0	+1.2	+ .8	+1.7	+1.7	+ .4	+ .8	+ .1
1929....	+1.1	+ .2	+ .8	+2.0	+2.3	+2.7	+2.3	+3.1	+4.4	+2.7	+3.6	+2.9
1930....	+3.2	+4.4	+1.4	0	+ .4	+ .9	+1.4	+1.1	+2.1	+3.0	+3.5	+3.5
Means..	77.5	78.0	77.6	77.9	79.4	80.2	81.3	81.9	81.8	82.0	80.6	78.9

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MAXIMUM TEMPERATURE

Station. Eleele

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1917....	+4.8	+5.4	+5.6	+2.5	+2.2	+ .9	+1.7	+4.7	....	+1.0	— .7	—1.6
1918....	0	—2.7	—3.3	—3.2	— .8	— .9	....	— .9	0	— .1	—2.0	—2.4
1919....	+ .2	— .8	—1.1	+1.4	—2.2	—2.6	—4.0	—2.0	— .6	+1.3	+1.1	— .2
1920....	+ .7	+ .3	— .6	+ .1	+1.6	—1.5	—2.0	—2.7	—3.5	—3.0	—2.1	—2.2
1921....	—5.0	+ .2	—1.6	—3.0	+1.0	—1.0	—2.0	—3.5	—3.5	—1.3	—2.2	—3.2
1922....	—2.0	—3.4	—2.0	— .7	—3.1	— .8	0	+ .1	+1.4	+ .7	— .4	+3.2
1923....	—1.6	— .9	—2.1	—2.0	+ .1	—1.0	—1.5	+ .1	+1.8	+1.2	+ .1	—2.9
1924....	—1.4	—2.6	—2.1	—1.9	—2.4	— .4	—3.7	....	—3.2	—3.0	—1.9	—2.4
1925....	+ .5	+1.6	+ .2	+ .1	— .5	+ .7	+1.8	—1.0	— .1	+ .4	— .3	+2.7
1926....	+1.7	+ .5	+1.5	+ .2	+ .9	+ .9	+1.9	+ .3	+ .4	+ .3	+4.8	+5.1
1927....	....	....	+1.5	+ .7	— .8	+ .7	+ .1	— .3	+ .9	+ .4	+1.4	+ .6
1928....	+ .7	— .3	+2.1	+2.3	+ .6	+1.5	+ .6	+ .7	+ .7	— .3	—1.5	+ .4
1929....	+ .9	+ .4	+1.6	+2.3	+1.7	+2.9	+3.2	+2.9	+3.9	+2.8	+1.5	+1.1
1930....	+1.0	+2.6	+ .6	+1.3	+2.0	+1.2	+3.3	+1.1	+1.7	+ .7	+1.6	+2.8
Means..	77.8	79.0	79.1	79.6	81.7	82.6	82.9	84.4	84.0	83.5	81.0	78.8

Station: Kealia

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—4.4	—2.1	—2.8	—3.2	—2.8	—2.6	—2.9	—3.0	—2.6	—2.4	—2.4	—3.4
1906....	—1.2	—1.0	—2.6	—1.8	—2.1	—1.5	—2.2	—2.4	—2.5	—1.6	—1.3	—1.8
1907....	—1.1	....	—8.0	....	....	....	....	....	....	—2.1	—2.8	—1.5
1908....	....	....	—2.1	—2.5	—3.4	—3.5	—3.8	—3.8	—4.4	—4.4	—2.8	—2.2
1909....	—2.1	—3.4	—3.5	—2.2	—3.6	—3.4	—4.1	—4.3	—4.0	—3.7	—2.3	—1.2
1910....	—3.2	—3.6	—1.8	—2.8	—3.7	—3.9	—3.1	—3.4	—1.7	—2.5	—2.4	—2.9
1911....	—3.4	....	+ .1	—1.5	—1.5	—2.4	—2.9	—2.3	—4.5	—3.4	—2.4	—1.8
1912....	— .5	—1.1	—3.0	— .8	—2.2	—1.6	—2.1	—1.9	—1.6	—1.3	....	+ .2
1913....	+1.2	— .4	+ .1	—1.0	— .6	+1.3	— .6	+ .3	+ .3	+1.2	+ .9	— .1
1914....	— .7	....	— .2	— .2	—1.3	+ .5	+ .7	— .2	— .6	+1.1	+ .9	0
1915....	+ .8	— .9	+3.1	+1.4	+ .9	+1.7	+1.0	+1.0	+1.2	— .2	— .7	+ .4
1916....	+1.6	+3.7	+3.7	+4.8	+1.0	— .2	— .3	— .7	— .4	+1.2	+ .8	+ .8
1917....	+ .6	— .9	—1.4	+ .4	+ .7	0	+ .1	+ .9	+1.3	+ .9	+1.5	+2.0
1918....	+2.2	+ .4	— .9	—2.9	+ .3	+ .5	0	+ .2	+ .8	+ .9	+ .8	— .7
1919....	— .3	—4.2	+1.0	+1.2	+ .2	+1.7	+1.3	+1.3	+ .7	+1.7	+1.9	+1.9
1920....	+ .8	+2.0	....	+ .5	+2.8	+1.1	+ .7	+1.4	+1.0	+1.4	+ .8	+ .8
1921....	—1.5	+1.8	+ .8	+1.4	+ .7	+1.2	+ .7	— .1	— .3	—1.1	+ .6	—1.2
1922....	+ .4	— .4	+ .7	+1.0	+ .7	+ .3	+1.2	+1.2	+ .1	+ .2	— .4	+1.3
1923....	—1.4	—2.4	— .7	— .1	— .2	— .1	0	+ .1	+ .6	+1.0	+ .2	— .7
1924....	+ .3	+ .6	+ .8	— .9	+ .3	+ .8	+ .6	+1.0	+ .9	— .1	+ .5	+1.3
1925....	+2.5	+2.5	+2.9	+1.4	+1.4	+1.1	+ .9	+1.5	+1.5	+1.8	+1.5	+1.1
1926....	+2.8	+2.6	+4.7	+2.2	+3.6	+2.5	+3.9	+2.3	+2.7	+3.6	+2.6	+3.0
1927....	+2.4	+3.4	+3.3	+2.5	+2.7	+3.9	+2.4	+2.7	+2.6	+2.3	+2.4	+ .4
1928....	+2.4	+1.5	+3.9	+3.0	+2.1	+2.1	+3.9	+2.2	+2.2	+1.3	—1.0	+1.2
1929....	+1.8	+2.2	+2.5	+2.3	+3.0	+2.8	+2.7	+3.7	+4.7	+2.2	+ .3	—1.0
1930....	+1.2	+2.5	+ .7	+ .2	+1.9	+1.1	+1.8	+2.1	+1.5	+2.4	+3.2	+2.9
Means..	78.2	78.8	78.7	79.8	81.6	83.1	84.3	85.0	85.3	84.1	81.8	79.8

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MAXIMUM TEMPERATURE

Station: Kilauea

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—2.8	—1.5	—1.2	—2.0	—2.3	—1.7	—1.9	—1.8	— .9	—1.3	—1.1	—1.5
1906....	— .8	0	—2.0	+1.1	+ .5	+1.3	+ .5	+ .1	+ .3	+ .4	+ .7	— .9
1907....	— .3	+ .1	—2.3	— .9	+ .4	— .2	— .7	—1.3	+ .1	— .2	— .5	+ .1
1908....	+ .1	— .1	+ .3	— .4	—1.0	—1.4	— .7	+1.5	—1.8	—2.3	+ .3	— .5
1909....	+1.1	—1.8	—2.7	0	— .4	— .3	— .9	—1.2	— .3	—1.3	+ .9	+ .1
1910....	— .3	—1.6	+ .8	+ .4	— .5	—2.3	— .9	—1.0	+ .6	— .6	+ .2	— .5
1911....	—3.2	—2.4	— .1	+ .5	— .8	—1.5	—1.1	— .3	—2.4	— .9	— .2	— .7
1912....	+1.5	— .1	—2.1	— .6	— .6	— .3	— .9	— .8	+ .1	0	+ .1	+ .6
1913....	+ .2	—2.0	+ .4	+ .3	+ .2	0	+ .2	+1.2	+ .8	+ .7	— .3	—1.1
1914....	—3.9	+ .3	— .9	— .7	—2.8	—1.9	—1.9	— .8	—2.4	—1.9	— .9	—2.1
1915....	— .9	—2.8	+1.7	— .3	+1.1	+1.3	+1.4	+2.5	+1.6	— .4	—1.4	—1.0
1916....	+ .3	+1.2	+1.4	+2.4	— .4	—1.3	— .9	—1.7	— .6	—1.1	—1.1	—1.3
1917....	—1.7	—1.3	— .8	+1.1	+1.1	—1.5	— .5	0	+ .6	+ .9	+ .9	+1.8
1918....	+ .3	— .6	—2.7	—2.9	—1.6	—1.6	—1.5	—1.1	+ .1	+ .1	— .6	—1.2
1919....	—1.3	—2.7	— .4	+ .8	— .5	+ .3	— .6	— .5	+ .8	+1.1	+1.9	+ .9
1920....	+ .9	+ .6	— .2	— .4	+1.5	+ .2	— .1	0	— .9	— .4	— .8	+ .2
1921....	—2.1	+2.1	+1.7	+1.2	+1.2	+1.8	+2.5	+ .7	— .2	0	— .7	— .3
1922....	— .4	—2.1	+ .2	+ .5	—1.3	+ .7	+1.3	+ .2	—1.1	+ .1	+ .5	+3.0
1923....	— .7	—1.9	—1.2	— .4	+ .4	+ .5	+ .3	+1.6	+ .8	+ .5	+ .8	+1.6
1924....	+1.5	+ .8	+1.0	—1.4	— .8	+ .5	— .2	+ .6	+1.3	— .5	+ .6	+1.5
1925....	+1.5	+2.2	— .9	....	+2.3	+1.0	+3.0	+1.8	+2.3	+2.5	+3.2	+4.5
1926....	+4.9	+3.3	+1.9	—5.1	—2.2	—2.8	—1.0	—1.4	—2.0	—2.7	—4.7	....
1927....	+6.2	+2.4	—2.2	— .5	—2.0	+3.4	+ .5	+ .4	— .6	— .2	—1.6	—4.3
1928....	—2.7	+3.9	+6.0	+3.2	+2.2	+1.6	+ .9	+1.3	+1.0	+2.2	+ .7	+2.0
1929....	+1.2	+1.3	+2.6	+3.8	+3.3	+2.5	+2.1	+3.3	+3.2	+2.1	+1.1	— .1
1930....	+1.2	+1.6	+1.0	— .6	+2.2	+1.9	+1.5	— .5	+ .9	+3.5	+2.3	....
Means..	76.4	77.4	76.8	77.8	79.9	81.5	82.4	82.9	83.0	81.7	79.1	77.3

Station: Koloa

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	+ .3	+1.4	+2.1	+ .3	— .1	+ .7	+1.6	+ .3	+ .2	+ .6	+1.9	+1.2
1906....	+1.9	+1.5	— .8	+1.6	+ .9	+2.3	+1.9	+1.0	+1.0	+1.8	+1.9	+ .6
1907....	+2.0	+1.2	—1.5	— .8	+1.4	+ .6	+ .3	—1.4	+1.3	+ .5	+1.4	+2.3
1908....	+2.2	+1.6	+1.5	— .2	— .6	— .6	— .1	+ .1	— .6	— .6	+1.4	+ .9
1909....	+1.0	—1.0	—2.6	— .1	— .8	— .5	—1.6	— .5	— .7	— .8	+1.7	+ .9
1910....	— .5	+ .2	+ .6	—1.5	—1.3	—1.8	+ .2	— .4	+ .7	+ .4	+1.4	+1.4
1911....	— .2	— .5	+1.4	+1.4	0	— .4	0	+1.4	—1.2	+1.2	+2.6	+2.7
1912....	+3.8	+1.2	—1.0	+1.2	+2.3	+2.3	+1.0	+1.3	+ .6	+1.1	+ .6	+2.2
1913....	+2.6	— .1	+1.5	— .2	+ .9	— .1	+ .7	+2.1	+1.9	+2.5	+ .1	+1.4
1914....	—1.6	+2.2	+ .7	+ .4	—1.3	—1.2	— .5	—1.0	—2.1	— .4	+ .6	+ .3
1915....	+1.0	—2.5	+1.4	0	+2.2	+ .8	+1.4	+ .5	0	—1.2	—1.0	+ .2
1916....	— .5	+ .9	+ .4	+1.6	—1.2	—2.1	—1.0	—1.6	—1.0	— .8	— .7	—3.7
1917....	+ .4	— .3	—1.2	— .5	— .8	—1.8	—1.6	—1.0	— .3	— .7	— .6	— .5
1918....	— .5	—2.4	—4.0	—4.4	—2.4	—1.5	—2.8	—2.2	—1.2	—1.6	—1.4	—2.3
1919....	—1.8	—1.5	—1.4	— .7	—1.9	+1.2	+ .2	+ .5	+ .6	+ .7	+ .5	+ .4
1920....	+1.0	+1.3	+ .4	+ .2	+1.9	+ .2	+ .1	+ .6	— .8	— .6	—1.4	0
1921....	—2.0	+1.9	+1.1	+1.0	+2.0	+1.8	+ .1	— .4	—1.0	— .2	—1.1	—1.8
1922....	—1.5	—3.0	— .9	+ .5	—1.4	— .3	+ .5	+ .1	—1.1	— .1	— .3	+1.7
1923....	—1.5	—1.2	— .6	+1.1	+ .3	+ .7	0	+1.0	+1.5	+ .5	+ .5	—1.9
1924....	— .2	+ .1	+ .4	+ .2	— .5	+ .1	—1.0	—1.2	+ .1	—1.4	— .2	—1.6
1925....	—2.6	+1.1	+ .3	—1.8	—1.4	—1.1	— .2	— .5	— .2	+ .6	— .4	+ .1
1926....	+ .8	+ .3	+1.6	+1.2	+2.8	+1.3	+1.6	+1.3	+ .5	+1.7	+1.2	+1.5
1927....	+ .4	+1.2	+ .5	+ .1	— .8	+ .8	— .4	+ .2	+ .7	+ .4	— .8	—1.3
1928....	— .5	—1.7	+2.0	+1.1	— .3	— .5	—1.6	— .5	—1.6	—1.7	—2.2	....
1929....	—1.5	—1.2	— .2	+ .4	+ .3	+ .3	+1.1	+ .8	+1.5	— .6	—1.8	—3.2
1930....	—2.0	+ .1	—1.3	—2.6	— .1	— .7	+ .4	— .3	+ .2	— .4	—3.5	— .4
Means..	76.2	77.4	77.5	78.3	80.0	81.2	81.9	82.7	83.2	82.2	79.5	77.3

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MAXIMUM TEMPERATURE

Station: Lihue

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— .9	— .1	+1.0	— .9	— .7	0	— .5	— .7	— .9	—1.3	+ .1	— .5
1906....	+ .7	+1.6	— .8	+1.5	+1.2	+1.8	+1.7	+1.0	+1.6	+3.2	+2.8	+1.4
1907....	+1.9	+3.3	+ .4	+1.7	+2.6	+1.8	+1.4	—1.6	+ .3	+ .6	+ .4	+ .2
1908....	+ .8	+ .4	— .1	+ .2	— .3	— .6	— .8	— .9	—1.8	—1.9	— .2	— .4
1909....	— .3	—1.1	—2.4	—1.0	— .7	+ .1	— .3	— .1	—1.1	—1.0	0	—1.4
1910....	—2.0	—1.5	— .3	—1.3	—1.6	—3.2	—1.2	—2.1	+ .3	— .9	0	—1.0
1911....	—2.3	—2.7	— .3	+ .1	—1.1	— .8	+ .5	— .2	—1.7	—1.0	+ .3	— .4
1912....	+1.3	0	—2.4	+ .2	+ .6	+1.2	+1.1	+1.0	+1.1	+ .9	+ .1	+1.4
1913....	+1.5	— .8	— .1	— .9	—1.1	—1.1	— .6	+ .4	— .1	+1.0	—1.1	— .4
1914....	—2.7	+ .2	— .6	— .4	—3.0	—1.8	—2.0	— .8	—2.2	—1.0	— .5	—1.0
1915....	—1.3	—3.2	+1.0	— .5	+1.0	+ .1	+ .2	+ .6	+ .8	—1.9	— .5	+ .4
1916....	....	— .5	+ .1	+ .9	—1.4	—1.6	—1.7	—2.5	—1.8	—2.2	—1.5	—2.1
1917....	—1.3	—2.5	—2.8	—1.0	—1.0	—1.6	—1.7	—1.7	—1.3	— .9	+ .4	+ .1
1918....	— .3	—1.4	—3.1	—3.6	—2.1	—1.0	+ .3	— .3	— .3	— .1	— .1	—1.4
1919....	—1.4	— .7	— .1	+ .2	— .9	— .1	— .5	+ .4	0	0	+1.3	+1.0
1920....	+ .2	+ .7	+ .5	+ .4	+1.5	— .2	+ .2	+ .2	— .7	— .4	+ .4	+ .9
1921....	+2.0	+2.7	+1.3	+1.1	+1.6	+1.4	+1.6	+ .7	+ .1	— .1	+ .3	— .8
1922....	— .1	—1.6	— .6	+1.0	+ .1	+ .5	+1.4	+1.3	— .4	— .3	— .9	+1.4
1923....	—2.1	— .9	— .8	0	+ .4	+1.1	+1.8	+1.1	+1.2	—1.0	—5.8	—3.5
1924....	0	+ .3	+ .5	+ .2	+ .5	+ .9	+ .1	+ .4	+2.3	0	— .1	+1.2
1925....	+1.6	+2.2	+1.5	— .3	+ .6	+ .2	— .3	+ .8	— .2	+1.5	+ .4	+1.9
1926....	+2.1	+1.9	+2.5	+1.8	+2.5	+1.2	+1.4	+1.6	+2.0	+3.6	+2.5	+3.1
1927....	+1.1	+2.3	+1.4	+ .7	— .5	+ .3	— .4	+ .5	+1.0	+1.2	+ .4	— .8
1928....	+ .6	+ .3	+2.7	+ .7	— .1	+1.4	—1.0	+ .2	+ .2	+ .8	—1.1	— .6
1929....	— .5	— .4	+ .4	+ .8	+1.1	— .1	+ .1	+ .5	+1.8	+ .9	+ .3	—1.2
1930....	+ .7	+1.8	+ .8	— .7	+1.1	+ .3	+ .2	— .2	+ .3	+1.4	+1.8	+1.7
Means..	76.9	77.3	77.5	78.3	80.4	82.2	83.3	83.9	84.0	82.6	79.8	78.1

Station: Makaweli

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	+ .1	+2.2	+1.1	+1.9	+1.4	+1.1	+1.3	+1.6	+1.9	+1.6	+2.7	+1.3
1906....	+ .9	+2.0	0	+3.2	+2.2	+3.8	+2.0	+1.5	+1.6	+1.4	+1.2	—1.3
1907....	—1.2	—1.2	— .7	—2.3	—1.4	— .6	— .6	— .9	+ .2	+ .3	+ .8	+1.9
1908....	+ .9	+1.2	— .3	— .9	+ .5	— .5	— .7	— .4	— .1	— .1	+ .8	+1.0
1909....	+ .4	—1.1	— .7	—2.0	— .9	— .7	—1.3	—1.8	—1.6	— .4	+ .6	— .6
1910....	— .6	— .4	+1.1	— .7	—1.7	—1.7	—1.5	—1.6	—1.0	—1.0	— .7	— .5
1911....	—1.9	—1.7	— .9	— .8	—1.8	—2.3	—3.3	—1.5	—2.6	—1.8	— .7	+ .3
1912....	+2.5	+1.8	— .4	+ .6	+ .3	— .5	— .4	+ .2	— .3	+ .8	+1.1	+1.4
1913....	+2.8	+1.0	+2.3	— .3	— .3	—2.1	— .4	+1.5	+1.8	+1.6	— .1	+3.2
1914....	0	+2.8	+1.9	+ .5	— .7	+ .1	0	+ .4	— .6	+ .1	+1.0	+ .8
1915....	+ .9	— .3	+1.4	+ .8	+ .9	+1.1	+ .7	+ .1	+ .3	— .9	—1.3	+4.7
1916....	— .5	+ .3	0	+ .2	— .9	—2.2	—1.3	—1.0	—1.5	+ .2	— .1	—1.0
1917....	+ .1	+ .9	— .8	— .6	— .9	— .5	—1.2	—1.2	+ .4	+ .1	+2.5	+2.8
1918....	+3.3	+ .2	— .7	—1.7	—1.2	— .4	— .7	+ .6	+ .2	+1.5	+1.5	+ .6
1919....	+2.8	+1.6	+2.4	+3.1	+1.2	— .2	— .6	0	— .5	— .6	0	— .5
1920....	+ .3	0	0	—1.1	— .8	— .6	+ .1	+ .2	— .5	—2.1	—6.9	—6.7
1921....	—7.3	—5.3	—4.5	—2.8	+ .5	+1.4	+ .4	—1.0	— .2	+ .5	— .2	—2.2
1922....	— .1	—1.3	— .4	+1.0	— .6	+ .7	+2.6	+ .5	0	+ .7	+ .3	— .6
1923....	— .8	—2.0	—1.1	— .5	— .7	— .6	+ .4	— .3	+1.0	+ .5	+ .4	—1.6
1924....	— .5	0	+ .7	— .2	0	+ .8	+ .1	— .1	+ .6	—1.5	—1.0	— .7
1925....	+ .1	+ .7	+ .5	—1.1	— .2	— .4	— .4	— .3	+ .1	0	— .4	—1.0
1926....	— .1	— .8	+1.2	+ .5	+1.7	+ .3	+1.1	+ .8	+ .3	+1.1	+1.1	+ .6
1927....	— .2	+ .4	+ .1	+ .5	+ .4	+1.6	+ .2	+ .7	— .2	0	— .2	— .8
1928....	— .4	—1.5	+ .9	+1.8	— .3	+1.0	— .2	+ .2	0	— .8	—2.4	— .9
1929....	— .3	— .7	+1.0	+1.1	+ .9	+1.4	+ .8	+ .8	+1.5	+1.1	— .8	—1.0
1930....	— .5	+1.3	— .4	— .8	+2.1	+1.2	+1.8	+ .1	—1.4	+ .3	+ .1	....
Means..	78.7	79.8	80.0	81.4	83.4	85.1	86.4	87.2	86.7	85.4	82.7	80.7

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MAXIMUM TEMPERATURE

Station: Hana

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1907....	....	....	....	....	+5.2	+3.8	+ .6	—1.0	+ .6	—1.2	— .7	+1.2
1908....	+4.3	+4.8	+3.9	+3.7	+ .7	— .3	+ .5	— .6	—4.2	—4.3	—3.8	—5.9
1909....	—3.5	—6.0	—5.3	—2.1	+ .4	— .6	—1.9	— .1	+ .2	— .3	+ .4	—1.1
1910....	—4.2	—2.0	—1.0	— .1	—1.1	— .8	— .2	—1.3	— .2	— .3	— .1	—3.4
1911....	—3.2	—3.9	+ .8	— .6	— .4	+ .6	+1.2	+ .2	—2.7	+1.4	+ .1	— .6
1912....	+ .8	—1.5	—3.7	— .3	— .1	—1.9	—1.6	+ .6	+ .8	— .2	— .3	+1.0
1913....	+1.4	—1.6	— .3	— .4	—1.9	0	+ .7	+ .4	+ .2	—1.2	—1.2	+1.0
1914....	—1.8	— .1	— .1	—2.5	—1.7	— .6	—1.4	0	—1.7	— .5	+ .4	+ .8
1915....	+3.9	+4.0	+4.3	+4.3	+4.7	+2.4	+1.0	+1.4	— .6	—1.0	+ .4	+3.2
1916....	+4.1	+4.3	+6.2	+4.6	+2.2	+2.1	+1.6	....	....	....	....	—1.7
1917....	+ .7	— .3	—1.1	+ .5	— .6	+ .4	+1.3	+1.5	+2.1	+1.0	+1.1	+1.8
1918....	— .5	— .2	—2.6	—3.0	—2.4	— .2	— .3	+ .5	+ .2	+ .2	— .9	—2.2
1919....	—1.6	—1.6	—1.5	+ .4	—1.3	— .8	— .9	—1.1	—1.0	— .7	— .6	+ .7
1920....	+ .6	— .2	—1.6	— .4	+1.0	+ .3	+ .8	+ .6	— .4	—1.0	—1.9	+ .8
1921....	— .7	+1.0	+ .5	+ .3	+ .3	+ .7	— .9	—1.0	— .6	— .5	—1.4	+ .8
1922....	+ .1	—3.2	—1.0	0	—1.3	— .9	+ .6	+ .4	+ .9	+1.3	+ .4	+2.0
1923....	+ .3	— .7	—1.0	— .5	+ .1	+ .2	0	+ .8	+1.1	+1.1	+1.0	—1.0
1924....	— .1	+1.5	—1.3	+ .3	—2.8	—3.4	—1.5	—1.7	+ .9	—1.0	+2.2	+3.1
1925....	+ .8	+ .4	0	—1.8	—1.6	—1.7	— .1	— .6	— .2	+2.2	+ .4	....
1926....	....	+2.8	+3.3	+ .2	+2.4	+1.6	+2.3	+1.6	+1.5	+2.3	+2.3	+1.9
1927....	+ .5	+1.8	+1.2	—1.1	+ .1	— .2	+ .2	— .8	+ .5	+ .4	+1.7	—1.4
1928....	+ .8	+ .3	+2.5	+ .3	—1.6	—1.0	—1.8	—1.2	—1.0	+ .2	+ .2	— .9
1929....	—1.5	—1.9	— .5	+ .5	— .3	+ .1	+ .7	+ .8	+3.1	+2.8	+ .1	—1.4
1930....	— .5	+2.7	—1.0	—2.4	— .4	—1.0	—1.3	— .2	+ .3	— .1	— .1	+ .8
Means..	77.8	78.4	77.8	78.2	80.1	81.2	82.0	82.4	83.1	82.5	80.6	79.2

Station: Kaanapali

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—4.7	— .8	+ .1	— .7	— .4	0	0	—3.5	—8.6	—7.6	—6.8	—7.1
1906....	—6.2	—5.4	....	—6.7	—1.4	— .4	— .4	—1.5	— .1	0	—1.0	—1.1
1907....	— .9	— .6	—1.8	—2.2	+ .2	— .4	— .6	—1.4	—1.1	—1.8	—1.2	+ .5
1908....	0	+ .9	+ .4	0	—1.3	—2.6	—2.3	—1.5	—1.2	—1.3	—2.1	—1.0
1909....	—1.0	— .9	—2.2	0	+ .7	— .5	—2.1	—2.0	—1.4	—1.5	— .2	—1.8
1910....	—3.7	—1.9	+ .4	— .4	—2.4	—2.2	—2.4	—1.6	— .7	—2.3	— .3	—1.1
1911....	—2.1	—2.0	—1.5	+ .8	0	—1.0	— .1	+ .1	—1.1	—1.4	— .5	— .5
1912....	+ .5	—1.4	—4.7	— .3	—1.1	—1.2	— .6	—1.0	— .3	— .5	— .5	+1.0
1913....	+1.5	+ .1	+1.9	+1.0	—1.8	— .1	+ .2	+ .2	+ .1	+ .5	+ .1	+ .2
1914....	—2.4	+ .8	— .1	— .4	—1.0	— .4	+ .6	— .6	— .9	—1.0	— .9	—1.9
1915....	— .4	—2.6	+ .5	+1.2	+2.2	....	....	....	....	....	....	— .1
1916....	—1.2	+1.3	— .2	+1.7	—1.6	—1.3	— .9	—1.0	— .2	+ .1	+ .1	—1.5
1917....	+ .1	— .9	+ .8	+2.5	+1.8	+1.5	+1.5	+1.1	+ .9	+1.3	+ .6	+1.2
1918....	+ .4	—1.3	—1.5	—3.3	— .7	+ .6	+ .5	+ .8	+1.3	+1.0	— .4	— .1
1919....	— .2	+ .6	+ .6	+4.0	+ .7	+2.1	+1.3	+ .4	0	+ .5	+1.5	+ .5
1920....	+1.1	+1.5	+1.0	+2.1	+3.5	+1.6	+1.5	+ .9	+ .7	+ .6	—1.0	+ .4
1921....	— .4	+1.4	+ .9	+2.7	+1.1	+2.1	....	+1.5	+ .4	—1.6	—1.1	—1.1
1922....	— .2	—1.2	+ .6	+2.4	—1.4	— .2	+ .3	— .8	— .4	— .6	— .2	+2.8
1923....	+ .5	—2.1	— .9	— .3	— .5	— .7	— .1	— .5	— .1	+ .9	+ .4	— .2
1924....	+ .6	+1.1	0	— .8	0	0	— .8	— .9	— .3	—1.5	— .3	+1.0
1925....	+1.7	+3.1	+ .2	—1.7	—1.4	—1.7	+ .1	— .3	+1.0	+ .9	+1.2	—2.3
1926....	+ .5	+3.9	+ .2	—1.6	+ .2	0	— .2	+1.2	— .2	+ .9	+1.3	+ .9
1927....	+5.6	+3.0	+3.5	—1.4	+1.4	+1.6	— .1	+1.5	+2.1	+2.8	....	+5.9
1928....	+1.7	—3.5	+ .8	—2.3	....	....	+ .9	+1.8	+2.4	+4.7	+8.4	— .5
1929....	+7.2	+2.1	....	+3.5	+2.3	+1.8	+ .2	+2.7	+3.2	+3.2	+ .9	+ .5
1930....	+2.3	+4.7	+1.7	+1.3	+1.5	+1.1	+2.9	+3.7	+4.1	+2.5	+ .8	+4.4
Means..	79.9	80.7	81.3	82.3	85.6	87.2	88.3	89.2	88.9	87.6	84.5	81.6

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MAXIMUM TEMPERATURE

Station: Wailuku

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— .2	+1.9	+1.5	+ .6	+1.7	+2.2	+2.7	+2.1	+1.8	+ .4	+1.2	—1.5
1906....	—5.9	—6.5	—8.8	+1.1	+1.0	+2.4	+1.3	— .6	— .5	— .1	+ .9	— .7
1907....	+ .7	+ .4	—1.6	—1.6	+ .9	— .2	— .2	—2.7	—2.2	—2.8	—1.9	+ .5
1908....	+ .9	+1.2	+2.4	+1.2	+ .1	—1.6	—1.7	—1.9	—2.0	—1.5	—1.4	—1.7
1909....	+ .4	—1.4	—2.3	— .9	—1.2	— .2	—1.2	— .6	— .9	—1.3	+ .3	0
1910....	—2.1	—1.7	— .2	— .1	— .6	—2.3	— .5	—2.0	+ .5	—1.4	+ .8	—2.4
1911....	—2.5	—1.7	—1.1	— .6	—2.2	—3.1	—2.3	— .6	—3.1	—2.9	—2.5	—2.5
1912....	+ .7	—2.1	—3.8	—3.4	—1.7	—1.4	— .2	+1.3	+1.6	— .2	—1.4	— .8
1913....	+1.1	—1.3	+ .6	+ .1	+1.0	+1.9	+3.1	+2.4	—1.1	—3.5	—6.0	—6.4
1914....	—6.8	—5.0	—5.1	—4.1	—7.4	—7.7	—6.5	—1.5	—3.1	—3.3	—3.2	—4.4
1915....	—3.8	—4.8	— .1	—4.1	—4.9	—6.2	—7.1	—7.1	—3.1	—2.2	—1.9	— .5
1916....	— .6	+2.4	+1.5	+2.1	— .4	0	— .2	— .4	— .2	+ .2	+ .2	—1.4
1917....	+1.9	+1.3	+1.4	+2.9	+1.9	+1.1	+1.1	+1.2	+ .9	+1.6	+1.1	+2.6
1918....	+1.4	— .7	—2.8	—4.4	—2.6	—2.1	—1.6	— .9	— .7	+ .6	— .6	—1.0
1919....	— .3	+1.8	+ .6	+1.7	+ .2	+2.8	+ .1	0	+ .8	+1.7	+1.8	+2.4
1920....	+2.1	+2.2	+ .7	+1.2	+3.7	+1.2	+1.4	+ .9	+ .6	+ .2	— .1	+1.2
1921....	+ .4	+2.4	+ .9	+1.4	+1.9	+1.4	+ .2	+ .2	— .6	+ .4	— .6	— .5
1922....	+ .1	—1.2	+1.0	+1.5	+ .4	+1.7	+1.8	+ .7	— .5	+ .5	+ .2	+2.3
1923....	0	— .2	— .1	+ .6	+ .7	—1.0	— .7	+ .4	+ .4	+ .4	— .1	—1.0
1924....	+1.2	+1.2	+ .8	+ .1	+ .5	+1.3	0	—1.1	+ .2	— .6	+ .8	+2.8
1925....	+1.9	+2.0	+ .3	— .5	— .1	— .5	+1.6	+1.3	+1.7	+2.7	+1.0	+3.2
1926....	+3.1	+3.7	+3.8	+ .2	+1.7	+2.6	+2.5	+1.9	+2.1	+2.7	+2.3	+4.6
1927....	+2.7	+2.6	+2.2	0	+2.1	+1.9	+1.6	+ .3	+1.3	+1.7	+3.3	+1.8
1928....	+1.7	+ .8	+3.1	+2.3	+1.4	+2.2	+1.3	+2.0	+1.0	+2.0	+1.6	+1.0
1929....	+1.0	+ .1	+2.7	+2.9	+2.4	+1.9	+2.7	+3.0	+3.4	+1.3	— .2	—1.2
1930....	+1.1	+3.5	+1.4	—1.1	+ .7	+ .5	+1.9	+1.9	+2.5	+2.8	+3.3	+3.3
Means..	77.6	78.3	78.5	79.5	81.6	83.1	83.9	84.7	85.0	83.9	81.3	78.9

Station: Ewa Mill

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—5.1	—4.2	—3.8	—3.9	—3.9	—3.8	—3.8	—4.4	—4.7	—5.1	—3.5	—4.6
1906....	—4.2	—3.5	—4.2	+1.1	+ .5	+ .5	+ .3	+ .1	+ .5	+1.0	+1.1	+ .1
1907....	+1.5	+ .4	—1.3	— .7	+ .7	+ .6	— .1	— .6	+ .4	— .2	— .1	+1.3
1908....	+ .7	+ .5	— .3	— .7	— .1	—1.0	—1.1	— .8	—1.2	—1.1	0	—1.0
1909....	— .4	—1.2	—2.9	—1.1	— .4	— .1	— .8	— .7	— .3	— .4	+1.0	— .1
1910....	—1.0	— .8	+1.1	—1.1	—1.1	—1.3	— .5	— .7	—1.0	—1.1	— .6	— .9
1911....	—1.8	—1.7	— .4	+ .6	0	— .7	— .4	+ .9	— .9	—1.1	— .3	— .5
1912....	+ .5	— .3	—1.3	+ .4	+ .4	— .2	+ .4	+ .9	+ .8	+ .8	0	+ .9
1913....	+2.0	— .3	+1.6	+1.2	— .2	— .1	+1.3	+1.4	+1.1	+1.6	+ .6	+1.0
1914....	— .7	+1.0	— .4	+ .4	— .2	+ .8	+ .3	+1.4	— .1	+1.0	— .2	—1.4
1915....	— .7	—2.2	+ .3	— .2	+1.2	+1.7	+1.2	+1.7	+1.3	+ .2	—1.1	— .9
1916....	— .9	+ .8	+ .2	+ .5	—1.3	—1.9	—1.6	—2.5	—2.2	—1.7	—1.2	—1.4
1917....	— .4	—1.3	—1.0	— .7	— .3	— .6	— .1	— .3	+ .1	+ .1	+ .1	+ .4
1918....	+2.0	— .7	—1.3	—3.4	—1.3	—1.2	— .2	— .5	— .2	+1.2	+ .7	— .6
1919....	0	+ .4	+ .1	+ .5	0	+ .7	+ .4	+ .7	0	+ .1	+1.0	+1.0
1920....	+ .7	+1.6	+1.2	+ .4	+ .9	+ .2	— .1	+ .4	+ .9	+ .9	+ .3	0
1921....	— .3	+1.2	+1.3	+ .8	+ .2	+1.3	+ .7	— .1	— .2	— .9	— .3	+ .1
1922....	+ .7	—1.4	+ .5	+1.0	— .6	+ .3	+ .9	— .1	— .1	— .2	+ .3	+2.1
1923....	+ .3	0	+ .4	+1.3	+1.5	+1.5	+1.4	+1.7	+1.3	+2.0	+1.1	+ .1
1924....	+1.1	+1.7	+1.4	— .2	+ .8	+ .4	+ .6	+ .1	+ .7	+ .4	+ .5	+1.5
1925....	+2.9	+4.4	+1.9	— .4	— .3	— .7	+ .2	— .3	— .2	+ .9	+ .7	+1.3
1926....	+2.2	+1.4	+2.2	— .8	+1.1	+ .4	+1.3	+ .7	+ .8	+ .4	+ .5	+1.7
1927....	+1.4	+1.4	+1.0	+1.0	+ .4	+ .7	—2.8	0	+ .6	0	— .6	+ .1
1928....	+ .2	+ .4	+1.6	+1.7	— .1	+ .5	+ .2	+ .1	+ .2	+ .1	— .2	+ .1
1929....	+ .2	0	+1.3	+2.1	+ .5	+ .9	+1.5	+1.2	+1.2	+ .7	— .5	—1.1
1930....	+ .1	+1.9	0	— .4	+ .8	+1.0	+1.0	+ .6	+ .5	+1.1	+1.5	....
Means..	78.6	79.6	79.9	81.6	83.7	85.3	86.2	86.8	86.6	85.2	82.5	80.2

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MAXIMUM TEMPERATURE

Station. Kahuku

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—3.6	—2.5	—1.2	—1.0	— .2	— .5	— .8	— .7	—2.0	—2.4	—1.0	—2.7
1906....	— .8	— .7	—2.7	+ .7	+ .1	+ .3	0	— .6	—1.0	— .6	— .3	—1.5
1907....	+ .2	—1.3	—2.3	—2.3	— .2	— .2	— .5	—1.8	—1.3	—2.2	—1.4	— .5
1908....	—1.0	—1.5	— .5	—1.4	— .9	—2.2	—2.5	—2.4	—3.3	—3.2	—1.6	—2.3
1909....	—1.0	—2.5	—3.8	—2.1	—2.1	—1.9	—2.7	—2.9	—2.8	—3.4	—1.8	—2.1
1910....	—2.6	—2.9	— .7	—1.7	—2.4	—2.7	—2.1	—3.1	—1.9	—2.3	—2.0	—2.3
1911....	—2.2	—2.6	— .5	— .5	—1.2	—2.2	—1.9	—1.0	—2.2	—2.8	—1.7	—1.8
1912....	+1.4	— .8	—1.6	— .7	— .4	— .9	—1.0	— .7	— .8	+ .6	+1.2	+1.3
1913....	+2.4	+2.1	+2.2	+ .6	0	— .9	+ .1	+ .7	+ .5	+3.5	+ .8	+2.3
1914....	— .2	+2.8	+ .8	— .3	—1.2	— .7	— .1	— .1	—1.7	+ .1	+1.3	+2.7
1915....	....	....	....	+2.1	+ .9	+ .9	0	— .3	— .6	— .7	—2.5	+ .8
1916....	— .6	+1.5	+ .9	+3.5	+ .5	— .7	— .9	— .8	+2.7	+2.7	+1.7	— .1
1917....	+1.9	+4.1	+ .8	+1.7	+2.0	+ .5	+1.1	+1.9	+2.4	+2.3	+1.9	+1.3
1918....	+1.6	— .4	—1.2	—1.8	— .5	+ .1	+ .8	+1.3	+2.1	+1.8	+1.8	— .6
1919....	+ .3	+ .3	+1.3	+1.8	+1.8	+2.8	+2.0	+2.8	+1.8	+1.8	+3.4	+2.0
1920....	+2.1	+4.0	+1.5	—2.0	—2.9	+ .6	+3.8	+1.4	+3.2	+3.8	....	+6.4
1921....	+1.3	+3.3	+2.8	+1.3	+3.2	+3.5	+2.3	+1.8	+ .9	+1.3	+1.5	+ .2
1922....	+ .3	—1.4	+ .4	+1.6	+ .2	+1.1	+ .4	+ .5	0	+ .4	+ .7	+2.5
1923....	— .5	— .4	+ .3	+1.9	+1.6	+1.2	+1.4	+2.7	+1.7	—1.3	+ .4	—2.0
1924....	— .1	— .1	+ .5	— .1	+ .1	+ .8	— .7	— .8	— .6	—1.8	— .6	+ .1
1925....	— .1	+ .1	— .1	—1.7	—1.0	— .9	— .2	+ .1	— .4	+ .9	— .5	+ .8
1926....	+1.0	+ .2	+1.3	+ .2	+1.4	+1.1	+ .9	+ .5	+1.3	+1.0	+1.4	+1.2
1927....	+ .2	+1.4	+ .8	+ .2	— .1	+ .4	— .5	0	+ .3	+ .4	— .3	—1.6
1928....	— .3	—1.0	+1.8	+1.0	+ .2	— .3	—1.2	— .3	— .6	—1.1	—1.4	—1.4
1929....	— .5	— .8	+ .7	+1.4	+1.4	+ .8	+1.2	+1.6	+2.3	+1.7	— .8	—2.4
1930....	—1.0	+ .2	—1.0	—1.2	+ .1	+ .1	0	+ .5	— .5	+ .3	+ .5	+ .4
Means..	77.8	78.7	78.1	78.9	80.7	82.5	83.7	84.4	84.6	83.8	81.2	79.6

Station: Waialua

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	+ .5	+2.5	+1.9	+3.2	+1.7	— .4	—1.4	— .6	— .9	+ .2	+1.5	— .2
1906....	+ .7	+1.2	—1.9	+2.0	+ .2	+1.3	+ .7	+ .2	+1.3	+2.5	+1.8	— .8
1907....	+1.0	+ .6	—1.9	—2.4	+ .4	+2.2	+1.0	+ .4	+2.9	+1.5	+1.7	+2.6
1908....	+1.0	+2.0	+1.2	+ .5	+1.5	— .9	—1.5	— .6	—1.9	— .4	— .1	— .3
1909....	+1.6	— .7	—2.4	—1.3	—1.6	—1.3	—2.4	—1.7	— .4	— .7	+1.9	— .2
1910....	—1.2	— .9	+ .7	— .5	—1.9	—3.1	—1.3	—1.5	— .4	— .7	+ .7	— .3
1911....	— .9	—2.0	+ .4	+ .1	—1.4	—2.3	—2.5	—1.7	—2.3	—1.1	0	— .3
1912....	+1.2	— .8	—2.4	— .5	— .2	+ .3	+1.0	+ .9	+1.0	+1.6	— .3	+ .2
1913....	+1.2	—1.1	+1.1	+ .8	— .1	—1.1	+ .4	+1.1	+1.5	+ .9	0	—1.2
1914....	—2.9	+ .9	—1.0	—1.2	—1.2	0	+ .2	+ .6	— .5	—1.0	— .6	—2.5
1915....	—1.3	—2.9	+ .7	—1.5	+1.5	+ .5	+1.0	+2.7	+2.1	+ .9	— .5	+ .2
1916....	—1.3	+1.6	+2.0	+2.1	—1.3	— .6	— .4	—1.0	— .4	— .7	0	— .4
1917....	— .7	—2.0	— .5	+1.6	+ .1	—1.2	—1.1	— .1	—1.3	— .2	0	— .2
1918....	— .1	— .2	— .9	—2.7	+1.0	+2.3	+2.7	+ .7	+1.6	— .2	+1.0	— .3
1919....	— .7	+1.1	— .7	+ .5	— .1	+2.2	— .3	+ .4	— .7	— .8	— .3	— .6
1920....	+ .1	+ .3	—1.3	— .6	+ .3	— .1	— .1	+ .8	+ .1	+ .5	—1.2	— .3
1921....	—2.0	+ .7	— .6	+ .1	+ .1	+2.6	0	+ .9	+ .2	— .2	— .9	— .9
1922....	—1.1	—3.0	—1.8	— .2	— .5	— .8	+ .5	— .1	—2.0	— .9	— .8	+1.4
1923....	—1.1	—3.9	—2.3	— .7	— .8	— .2	+ .2	— .6	— .1	+ .6	+ .5	—1.0
1924....	—1.3	— .4	— .9	— .7	— .8	—1.4	—1.4	—5.2	....	—1.3	+ .3	+1.2
1925....	+1.2	+1.1	+ .4	— .6	—2.4	—2.4	—3.2	—2.5	—4.6	—4.0	....	— .9
1926....	+1.8	+ .9	+2.2	—1.3	+3.0	0	+ .9	+1.0	+ .2	— .7	+ .4	+1.6
1927....	+ .1	+1.2	+1.1	— .7	— .3	+1.9	+5.1	+4.7	+2.8	+3.7	— .8	+2.9
1928....	+3.7	+ .9	+4.2	+3.2	+3.1	+4.3	+3.5	+3.1	+1.0	+ .6	—2.8	— .3
1929....	— .9	+ .3	+1.5	+1.4	+ .7	+1.3	+1.3	0	+1.5	+1.9	— .6	— .6
1930....	+1.3	+1.8	+ .1	—1.3	—1.6	—3.0	—3.0	—1.2	+ .1	— .9	— .5	+ .8
Means..	77.7	78.5	79.3	81.1	83.8	85.9	87.1	87.2	86.4	84.2	81.0	78.8

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MAXIMUM TEMPERATURE

Station: Waianae

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	....	— .3	— .5	+ .3	+ .7	+ .5	— .9	— .2	+ .4	— .4	— .6	—1.0
1906....	— .6	0	—3.2	+1.2	+ .6	+2.4	+1.3	+1.2	+1.0	+1.2	— .9	—1.3
1907....	— .9	— .8	—2.1	—1.9	— .4	0	— .4	— .4	— .5	—1.4	—1.0	+ .2
1908....	— .6	— .1	—1.7	—1.3	+ .1	— .2	— .1	—1.4	—1.6	—2.3	—1.7	—1.0
1909....	—1.6	—1.8	—1.6	—2.1	....	....	—1.3	— .9	— .6	—1.0	+ .4	—2.1
1910....	0	— .3	+3.0	+1.2	—1.2	—2.1	....	—1.1	—3.6	—2.0	—1.4	—1.4
1911....	—1.4	—2.0	—1.3	— .2	—1.2	—1.3	—1.7	—1.2	—1.3	—2.1	—1.5	+ .3
1912....	+ .8	0	— .5	+1.6	+ .6	—1.0	—2.1	— .8	+ .8	+1.9	— .7	+1.8
1913....	+1.3	— .4	+2.2	+2.0	— .6	—1.3	— .3	+ .1	+ .5	+ .3	— .4	—1.2
1914....	—1.5	— .6	—2.1	—1.4	—1.2	+ .1	0	+ .4	— .5	+1.5	+ .6	—1.3
1915....	— .6	— .6	— .1	+ .2	+1.6	+2.4	+1.2	+1.7	+1.3	+2.2	— .8	—1.3
1916....	—2.2	— .9	+ .5	+2.0	+ .8	+ .7	0	— .8	+ .3	—2.4	— .3	— .3
1917....	—2.1	—2.4	—2.2	— .8	+ .3	+ .2	— .3	0	+1.5	+1.0	+ .9	— .5
1918....	— .8	—1.3	—1.5	—4.1	— .1	+1.5	+2.3	+2.2	+1.8	+2.2	+1.2	+4.1
1919....	+1.7	+1.4	+1.4	+2.0	+1.1	— .3	+ .2	+ .1	— .4	+ .3	+ .1	+1.2
1920....	—1.3	0	— .4	— .2	—1.1	— .6	— .4	— .2	0	+1.4	+ .9	—1.3
1921....	—2.7	0	— .7	0	— .8	+ .6	— .7	—1.5	—4.5	—5.9	—5.0	—1.7
1922....	—1.1	—1.6	— .4	+1.0	— .8	— .2	— .3	— .7	—1.0	—1.7	— .7	+1.4
1923....	— .2	—2.2	—1.0	+ .1	+ .9	+ .2	+ .2	—1.0	+1.4	+1.3	+2.2	+2.1
1924....	+1.6	+1.3	+2.7	—1.2	— .7	—3.8	+1.4	+ .6	+1.0	+ .6	+2.2	+1.9
1925....	+2.9	+3.3	+1.5	— .6	—1.3	—1.3	— .3	+ .8	+1.4	+3.0	+4.4	+1.0
1926....	+3.5	+2.6	+2.5	—2.0	+1.2	+ .7	+1.2	+ .9	+1.4	—1.4	+4.3	+6.1
1927....	+6.7	+4.4	+4.1	+3.1	+1.1	+1.5	0	+1.2	0	+1.8	+1.4	—1.9
1928....	+ .6	— .2	+1.4	+ .5	—1.1	+ .1	— .4	— .3	— .2	+1.1	—1.0	— .3
1929....	+ .8	+1.4	+1.2	+1.7	+1.8	+ .7	+1.4	+ .3	+1.2	+ .4	—2.7	—3.8
1930....	—1.4	— .1	— .8	— .8	+ .8	+ .6	— .1	+ .5	— .3	+ .6	— .3	+ .4
Means..	80.7	81.2	82.0	83.5	85.5	87.1	88.8	89.4	88.7	87.4	85.1	83.0

Station: Waimanalo

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—2.5	+ .9	....	— .5	— .9	— .8	—2.3	—1.7	—1.6	+2.8	—2.0	—1.5
1906....	+ .4	+ .4	—2.5	— .3	+ .9	+1.7	+1.7	+1.3	+1.8	+2.3	+1.0	— .4
1907....	+ .9	+ .9	—1.5	— .6	+1.9	+1.3	+1.6	+ .1	+1.3	+ .7	+ .2	+2.4
1908....	+2.6	+1.4	+1.9	+1.5	+ .5	— .3	0	— .2	— .8	0	+ .7	+ .3
1909....	+ .9	— .7	—2.5	+1.0	— .1	+ .1	—1.5	+ .1	+ .6	— .9	+ .7	— .1
1910....	—1.6	—1.1	+ .3	— .2	— .8	—1.0	+1.0	+ .3	+1.2	—1.1	+ .2	—2.1
1911....	—1.8	— .8	+1.4	+1.0	— .2	— .7	+ .3	— .2	—1.3	—1.5	— .4	— .1
1912....	+2.4	— .9	—2.4	+ .1	+ .5	+1.7	+1.5	+1.1	+1.4	+ .2	— .1	+ .8
1913....	+1.4	— .9	+1.3	+1.5	+2.0	+1.2	+2.4	+3.5	+3.2	+3.3	+ .8	— .1
1914....	—1.8	+2.4	+ .6	+1.9	0	+1.3	+2.2	—1.1	—1.5	+ .1	+ .3	+ .1
1915....	+1.2	—3.8	+1.3	— .9	+1.9	+2.4	+2.0	+3.0	+2.4	— .4	—1.7	— .7
1916....	0	+2.5	+2.5	+2.6	— .6	— .8	— .8	— .9	— .6	—1.1	0	—1.9
1917....	—1.3	—1.6	—1.2	+ .6	+2.1	+1.6	+2.3	+2.8	+2.9	+2.3	+ .4	+ .5
1918....	+ .3	— .9	—2.3	—3.8	—2.1	—1.4	—1.2	+ .1	+1.4	+ .9	+ .3	—1.4
1919....	—1.0	— .1	+ .8	+1.4	+ .4	+1.1	— .6	— .7	+ .1	+1.0	+2.9	+1.5
1920....	+ .5	+1.2	+1.0	+2.5	+5.7	+3.4	+1.6	+3.4	+1.5	+ .8	+ .1	+1.4
1921....	—1.1	+3.2	+3.2	+1.3	+2.7	+2.9	+1.6	+1.2	+ .4	+ .2	+ .1	— .2
1922....	— .4	— .6	+1.3	+1.7	+ .8	+1.4	+1.7	+1.3	+1.1	+1.2	+1.3	+2.6
1923....	+ .3	—1.4	+ .1	+1.4	+2.0	+1.3	+ .4	— .2	—2.6	—4.2	—3.8	—4.4
1924....	—1.2	—1.8	—3.1	—3.7	— .3	—1.6	—2.1	—3.2	—3.7	—3.7	+ .7	+2.7
1925....	+3.0	+ .6	— .7	— .8	—2.4	—3.0	— .7	— .2	— .2	+1.9	+4.2	+7.6
1926....	....	+4.4	+ .3	—3.2	—2.3	—2.9	—2.9	—3.4	—4.0	—3.0	—1.4	+1.6
1927....	— .1	—2.7	—2.0	—4.5	—6.3	—5.5	—3.4	—1.1	—2.3	—3.9	—4.0	—4.8
1928....	+ .6	—1.4	+2.8	+2.6	—3.1	—1.5	—2.6	—1.4	0	— .8	—1.2	—1.2
1929....	— .3	+ .4	+ .1	+ .5	—1.0	—1.2	—1.5	—1.4	— .4	+2.5	— .8	—2.2
1930....	— .4	+1.1	—1.8	—2.3	— .9	—1.8	— .9	—1.3	—1.4	— .7	— .3	+ .7
Means..	77.6	78.6	78.9	79.8	82.3	83.9	84.9	85.4	85.4	84.3	81.3	78.6

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MAXIMUM TEMPERATURE

Station: Waipahu

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	....	....	....	....	....	....	....	....	....	....	....	....
1906....	+ .7	+1.0	—2.7	+2.7	+ .2	+2.2	+1.7	+1.0	+1.6	+1.8	+1.8	— .7
1907....	+1.3	+ .8	—1.6	— .6	+1.6	+1.9	+1.9	+ .9	+1.7	+ .4	+ .3	+3.3
1908....	+1.3	+ .3	— .7	+ .3	0	+ .4	+1.0	+ .7	— .3	+ .2	+1.2	0
1909....	— .6	—1.6	—1.7	— .6	+1.4	+1.4	+ .9	+1.1	+ .6	+ .2	+1.6	— .1
1910....	— .9	— .9	0	—1.2	—1.3	—1.3	+ .7	—1.2	— .9	—1.2	— .2	— .4
1911....	—2.1	—1.8	— .4	+1.0	— .7	— .3	— .4	+ .5	—1.2	— .7	— .6	—1.2
1912....	+ .7	—1.4	—2.7	—1.2	— .9	— .6	— .5	— .1	— .5	— .8	—1.7	0
1913....	+1.7	— .5	+ .5	— .8	— .4	— .9	+ .8	+1.1	+ .7	+1.4	—1.1	+ .4
1914....	—1.8	+ .9	—1.0	0	— .6	+ .4	+ .4	+ .7	—1.6	— .9	—1.1	—1.9
1915....	—1.2	—2.4	+ .3	+ .6	+2.1	+1.8	+1.4	+1.7	+ .6	—3.5	—2.2	—3.7
1916....	—1.1	+ .1	0	+ .9	— .7	—1.5	— .6	—2.4	—1.5	—1.7	—1.1	—1.2
1917....	— .9	—1.1	—1.9	—3.9	— .7	—1.0	+ .1	+ .3	+ .2	+ .4	+ .5	+ .5
1918....	+ .4	—1.4	—2.0	—3.3	—1.3	— .5	— .7	— .2	+ .5	+ .8	+ .2	— .8
1919....	—3.7	— .8	— .4	+ .9	— .2	+ .4	— .4	....	— .2	+ .5	+1.9	+3.8
1920....	+2.7	+1.9	+ .1	+1.2	+1.4	+ .7	+ .9	+1.2	— .2	+ .4	— .5	+1.6
1921....	—1.8	+1.5	+ .5	+ .5	+ .7	+2.3	+1.2	+1.0	— .3	+1.1	+ .5	— .5
1922....	— .7	—2.1	— .2	+ .9	—1.3	— .2	—1.0	+ .4	— .4	+ .2	+1.2	+2.0
1923....	—2.0	—2.1	—1.3	+ .5	+ .3	+ .9	+ .2	+ .3	+ .6	+ .4	— .6	....
1924....	....	....	—1.7	— .5	— .8	—2.3	—4.2	—5.0	—4.5	—3.9	—2.6	—2.1
1925....	+1.6	+ .6	+6.1	+ .5	— .4	—2.1	+ .2	+ .5	+2.4	+ .7	+2.5	+1.7
1926....	+4.0	+3.6	+5.5	— .6	+2.5	+2.3	+1.8	0	+1.5	+3.5	+2.9	+4.7
1927....	+3.2	+5.0	+3.4	+3.4	+1.7	+1.6	— .1	+ .5	+ .9	+ .9	+1.2	—1.6
1928....	— .2	+ .1	+1.9	+1.0	— .4	— .9	—2.5	—1.2	—1.5	— .8	—2.2	—1.4
1929....	— .2	+ .2	+2.6	+1.2	— .7	—1.6	—2.1	— .4	+2.2	+ .9	—2.7	—3.1
1930....	—1.5	+ .9	—1.7	—2.5	—1.8	—2.5	0	—1.4	— .8	+ .3	+1.5	+1.1
Means..	78.1	79.3	79.9	80.9	83.2	84.5	85.4	86.0	86.0	84.6	82.1	79.7

TABLE E

TEMPERATURE DEPARTURES FROM THE AVERAGE

BY MONTHS

MEAN MINIMUM TEMPERATURE

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MINIMUM TEMPERATURE

Station: Hakalau

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—2.4	—1.4	0	+1.3	....	+ .7	+3.5	+3.5	....	+2.7	+2.4	+1.6
1906....	+4.6	+2.1	—1.7	— .5	—1.2	0	+ .2	....	....	....	....	....
1907....	— .3	— .8	—2.6	—3.3	—2.3	—1.8	— .2	— .5	+ .4	— .2	— .8	— .7
1908....	—2.0	— .6	+ .2	—2.0	—1.7	—2.3	—1.8	—1.6	—1.2	—1.3	— .4	—2.3
1909....	—2.0	—1.1	—1.7	—2.0	—3.2	—1.9	—2.6	—3.7	—3.0	—2.4	—2.6	—2.5
1910....	—2.3	—2.1	—1.6	—2.1	—2.9	—2.7	—3.2	—2.7	—1.4	—3.1	—1.5	—1.6
1911....	—1.2	— .6	—1.1	0	—2.2	—1.4	—1.9	—1.2	—1.4	—2.1	—1.8	—1.3
1912....	—1.8	— .9	—2.2	—1.7	—2.1	—2.6	—2.3	— .5	—1.1	— .5	—1.3	— .6
1913....	+ .8	— .1	— .9	—2.3	—2.5	—1.2	—1.1	— .3	+ .2	+ .7	—1.1	—2.1
1914....	—2.0	0	+ .7	+3.0	+1.5	+1.5	+2.8	+3.0	+2.9	+3.3	+4.1	— .8
1915....	+ .6	+ .3	+1.3	+1.3	+3.7	+1.9	+1.5	+ .7	+1.0	+ .5	+1.4	+2.7
1916....	+3.1	+3.5	+3.8	+2.8	+ .9	+ .7	— .3	— .8	+ .2	+ .5	+ .2	+ .7
1917....	+1.8	+1.3	+2.0	+1.2	+ .2	+1.1	+ .1	+ .2	+1.2	+1.0	+ .9	+2.1
1918....	+1.9	+2.3	+1.0	+1.9	+11.7	+2.2	+1.8	+1.9	+1.7	+1.0	+ .5	+ .5
1919....	— .3	— .1	0	+ .7	— .9	— .5	— .5	— .3	+ .5	+3.8	+2.2	+1.6
1920....	+2.7	+2.5	+1.4	+1.1	+1.7	— .8	—2.2	—4.1	—4.7	—6.3	—7.7	—6.3
1921....	—6.8	—7.0	—8.7	—6.0	— .1	+ .7	— .3	—1.2	—2.5	—1.8	—3.3	—2.2
1922....	—3.3	—6.1	+1.2	+1.3	— .6	— .1	+ .4	+ .2	+ .2	+ .4	+ .7	+1.0
1923....	+ .8	+1.4	+ .8	+1.7	— .3	+ .9	+ .5	+ .7	+2.0	+1.8	+1.2	+1.1
1924....	— .7	+2.4	+1.0	+1.1	— .2	— .1	0	— .3	+1.0	—1.3	+ .8	+3.9
1925....	+1.0	+1.9	+1.4	— .1	— .9	— .8	— .2	+1.2	+1.2	+ .8	+1.9	+ .7
1926....	+1.1	+ .9	+1.1	—2.4	—1.9	+1.6	+1.8	— .9	—2.9	—2.8	— .9	+1.7
1927....	+ .8	— .1	0	+ .5	+ .2	+1.7	+ .1	+ .3	—1.2	—1.2	+1.8	+ .5
1928....	+1.2	0	+ .9	+2.1	+2.3	+1.8	+ .4	+2.7	+1.8	+1.0	+1.7	+ .7
1929....	+1.8	+1.2	+2.6	+1.9	+2.1	+2.0	+2.7	+2.4	+3.4	+2.8	+2.5	+1.7
1930....	+1.5	— .2	+2.0	+ .2	+ .1	+ .4	+ .7	+ .9	+2.7	+1.8	....	....
Means..	63.0	62.6	63.2	64.5	66.2	66.9	68.0	68.6	68.0	67.6	66.1	64.6

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MONTHLY MINIMUM TEMPERATURES

Station: Hilo

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— .4	—2.3	— .4	+1.5	+2.5	+2.2	+3.4	+2.7	— .9	....	0	—1.0
1906....	— .4	— .2	—1.9	0	— .4	— .4	— .5	— .5	— .4	— .5	—1.1	— .1
1907....	+ .2	+ .3	— .8	—1.9	— .8	— .1	— .9	— .4	— .5	— .9	—1.4	—1.1
1908....	—2.8	—2.5	+ .4	—1.6	—1.0	—1.7	— .5	—1.4	—2.5	—1.1	—2.2	—2.4
1909....	—2.2	—1.6	—2.2	—1.2	—2.6	—1.6	—2.9	—2.2	—1.6	— .7	+1.2	— .4
1910....	0	—2.6	—2.3	—2.6	—2.5	—2.7	—2.1	— .7	— .8	....	....	— .7
1911....	— .8	+ .1	— .5	+1.0	— .6	— .2	+ .4	— .2	— .8	— .8	— .9	—1.8
1912....	+ .5	+1.0	—1.8	— .8	—1.1	—1.1	— .8	+ .3	— .3	— .2	— .3	+ .3
1913....	+ .4	+ .1	— .5	—1.0	— .8	+ .1	— .3	+ .1	+ .5	+1.3	+ .9	+ .6
1914....	— .8	0	— .2	— .4	+1.5	+1.0	— .4	— .3	+1.8	+1.3	+ .1	—1.4
1915....	+ .4	—1.1	— .2	— .5	+2.1	+1.0	— .2	+ .2	+ .5	— .1	+2.3	....
1916....	+ .8	— .1	+2.3	+ .2	—1.4	—1.5	—2.7	—3.2	—3.6	—3.2	—3.3	— .9
1917....	— .7	—1.6	0	— .6	—1.6	—1.0	—1.9	—3.7	—3.0	— .8	—2.0	—1.1
1918....	+ .4	+1.7	+2.7	+1.4	+ .4	— .8	+ .8	+ .5	— .2	+ .1	0	+ .3
1919....	—1.8	— .8	+ .1	— .1	— .8	+ .2	— .5	+ .6	— .4	— .2	— .8	— .5
1920....	— .4	— .3	—1.6	— .6	+ .6	— .1	+ .6	+ .1	— .4	—1.4	—1.5	+ .7
1921....	+1.5	+ .2	+ .3	+ .8	+ .4	+ .3	+ .9	+ .4	— .1	+ .2	— .2	+1.2
1922....	— .2	+ .4	+ .6	+ .8	+ .2	— .2	+ .8	0	+ .2	+ .2	+ .3	+ .5
1923....	+1.4	+ .3	+1.0	+1.6	+ .3	— .4	+ .9	+ .6	+1.8	+1.1	+ .5	+1.4
1924....	—1.2	+2.4	—1.0	+1.5	+ .5	+ .9	— .1	+ .2	+ .2	+ .4	+ .6	+1.3
1925....	+ .5	+1.4	0	— .5	+ .5	+ .8	+ .4	+ .7	+1.4	+1.6	+1.3	+ .5
1926....	+ .5	+1.2	— .6	— .8	+ .5	+1.5	+2.1	+1.5	+2.1	+1.7	+1.4	+1.4
1927....	+1.8	+1.5	+1.6	+1.7	+1.6	+1.6	+1.1	+ .6	+ .7	+ .6	+1.6	+1.0
1928....	+1.2	— .4	+1.1	+1.3	+1.1	— .4	+ .3	+ .6	+1.0	+ .4	+ .9	— .1
1929....	+ .4	+ .5	+2.3	+ .9	+ .7	+1.3	+1.5	+ .9	+1.2	+1.3	+ .8	+ .3
1930....	+1.3	+1.8	+1.4	0	0	+ .5	+1.1	+1.6	+2.5	+ .7	+1.0	+1.3
Means..	62.5	62.2	63.0	64.2	65.2	66.4	67.4	68.1	67.5	66.9	65.7	64.0

Station: Honokaa

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—2.1	— .7	— .5	— .5	— .2	— .7	— .2	+ .9	+ .6	— .3	+ .1	— .9
1906....	+ .6	— .1	—1.6	+ .1	+ .1	+ .1	—1.1	— .6	— .8	+ .2	— .4	— .9
1907....	+ .6	—1.1	— .4	—1.9	— .1	+2.2	+1.1	+1.4	+ .3	— .5	+ .6	0
1908....	— .4	— .2	— .2	— .2	— .7	— .2	— .3	+ .5	+ .2	— .1	—1.3	+ .2
1909....	+ .3	— .6	— .3	— .6	— .4	+ .1	+ .4	— .4	— .6	+ .2	+ .1	— .7
1910....	+ .7	+1.1	+2.2	+2.9	+1.4	— .5	—2.7	—1.7	+ .5	+ .3	+ .7	— .6
1911....	— .9	—1.1	— .7	— .7	—1.1	—1.9	—2.1	—1.3	— .3	— .7	+ .6	+ .3
1912....	0	+2.6	+ .7	+2.3	+3.0	+3.3	+4.1	+2.4	+ .4	+1.8	+ .4	+1.8
1913....	+ .9	0	+ .1	—1.3	—2.5	—1.0	—1.5	—1.2	—1.4	— .4	— .5	—1.7
1914....	—2.7	—2.4	—2.3	—1.0	— .9	— .7	— .1	— .2	+ .4	—1.1	— .7	—2.8
1915....	—2.1	—3.3	—2.8	—1.8	— .7	—1.1	—1.8	—1.3	— .6	— .8	—1.9	—1.8
1916....	—1.2	— .7	+1.0	— .1	— .8	—1.8	—2.5	—3.2	—2.0	—1.3	—1.8	—2.2
1917....	—2.4	—3.1	—1.7	—2.1	—2.5	—1.6	—2.6	—2.5	—2.0	—1.6	—1.7	—1.1
1918....	—1.7	—1.8	—3.5	—2.1	—2.0	—1.6	—1.1	— .1	—2.1	—2.7	—1.6	—1.6
1919....	—3.4	—2.6	—3.0	—3.5	—3.5	—2.7	—2.5	—2.3	—2.8	—2.4	—2.4	—1.9
1920....	—1.6	— .1	— .2	— .3	— .1	+ .9	+ .7	+2.0	+1.7	+ .6	—1.5	+1.0
1921....	+1.9	+ .8	+ .7	— .9	+ .2	+ .8	+ .4	+1.6	—1.2	—1.5	— .8	+ .2
1922....	— .1	— .2	+ .8	+2.0	+ .5	— .4	+1.4	+ .5	+ .4	0	—1.9	—1.5
1923....	0	— .6	0	+ .9	— .1	— .5	—1.0	—2.1	—2.3	—1.4	— .3	+ .9
1924....	+ .4	+2.6	+ .2	+2.2	+ .8	+1.3	+1.3	+1.1	+1.3	+2.1	+1.7	+2.3
1925....	+2.9	+2.5	+1.0	+ .3	+ .6	+1.1	+ .4	+1.6	+1.9	+1.4	+1.9	+1.2
1926....	+1.9	+2.1	+1.4	— .4	+1.9	+1.1	+1.9	+2.5	+2.4	+2.5	+1.4	+2.4
1927....	+2.3	+2.6	+3.1	+2.1	+2.3	+1.9	+1.7	+1.4	— .8	+1.3	+2.7	+2.8
1928....	+2.3	+ .5	+1.2	+1.9	+1.4	— .2	+ .5	+ .7	+1.0	+ .8	+2.1	+1.6
1929....	+1.8	+1.0	+1.6	+2.1	+1.5	+1.4	+2.9	+2.2	+2.6	+3.7	+2.0	+2.1
1930....	+1.9	+3.0	+2.0	+1.4	+1.1	+1.5	+1.7	+3.2	+2.7	+ .8	+2.0	+1.0
Means..	61.0	60.8	61.8	62.7	64.5	65.7	66.6	67.3	66.7	65.8	64.1	62.6

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MINIMUM TEMPERATURE

Station: Kohala Mill

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—4.0	—1.6	+1.1	+ .2	+ .2	—1.9	—1.1	+ .9	— .4	— .5	— .4	— .6
1906....	+1.4	— .2	—1.3	0	—1.2	+1.2	0	— .5	+1.3	+1.1	0	— .3
1907....	+1.2	+ .7	— .7	—1.4	+ .3	+1.7	+ .3	+ .8	+ .5	— .1	— .1	+ .7
1908....	+ .2	— .3	+ .5	— .1	+ .1	—1.4	—1.6	—1.3	—1.7	— .9	—2.0	—1.4
1909....	— .9	—1.8	—1.8	—1.8	—1.5	+ .2	— .7	— .1	— .2	— .5	— .1	— .5
1910....	—6.3	—1.5	+ .3	+ .4	— .7	— .4	— .7	— .4	—1.3	— .9	0	— .8
1911....	+ .7	— .9	0	+1.2	+ .6	+ .5	+ .4	+ .3	— .3	—1.6	+ .5	0
1912....	— .1	+ .4	— .5	+ .7	+ .4	— .3	+ .5	+ .8	+ .2	+1.6	+ .9	+2.1
1913....	+1.5	+ .5	+ .5	+1.0	— .1	+ .8	+1.0	+1.1	+ .4	+1.5	+1.4	+ .6
1914....	— .3	+ .3	+ .1	+ .4	+ .5	+1.3	+1.4	+1.8	+1.4	+ .2	— .3	— .6
1915....	+ .4	—1.1	— .7	+ .5	+ .9	+ .8	+ .5	+ .2	+ .8	+ .8	+ .4	— .2
1916....	+1.3	+ .7	+1.5	+1.1	+ .3	— .9	—1.0	—2.6	—2.5	— .6	— .9	— .9
1917....	— .7	—1.7	— .7	— .5	—1.1	0	— .8	— .6	—1.4	—1.4	—1.4	— .6
1918....	— .6	—1.7	—2.9	—5.3	—6.6	— .3	+ .8	+1.0	+ .3	+2.0	— .6	—3.1
1919....	—3.7	— .4	+ .8	+ .5	+1.2	+1.3	+1.7	+1.2	— .2	+1.0	+ .2	+1.0
1920....	+ .3	+1.4	+ .6	+1.5	+ .9	+ .1	+1.3	+ .2	+ .1	+ .0	+ .9	+ .2
1921....	+ .9	— .9	—2.3	—2.0	— .4	—3.6	—6.3	—6.2	—2.9	—7.4	+ .6	+1.9
1922....	+2.6	+1.5	+ .6	+1.9	+ .7	+1.5	+2.3	+1.4	+1.5	+ .9	—1.1	+1.2
1923....	+1.7	+2.0	+1.2	—1.1	—1.7	—2.7	—1.6	—1.8	— .6	— .7	—1.6	— .9
1924....	—1.5	+1.4	—1.6	0	— .6	—1.2	—1.5	—2.0	—1.4	—1.2	—1.3	—1.3
1925....	+ .3	0	— .2	— .3	— .4	— .1	— .5	+ .2	+ .3	— .3	— .1	— .3
1926....	+1.0	— .2	+ .3	—1.1	+1.1	— .3	+ .7	+ .6	+ .6	+ .6	— .5	+ .9
1927....	+1.7	+1.1	+2.2	+1.4	+1.9	+ .6	+ .2	+ .1	— .5	+ .1	+ .5	+ .7
1928....	+ .7	—1.3	—1.2	+1.0	+1.0	— .2	+ .9	+ .9	+ .5	+ .4	+ .7	+ .3
1929....	+ .9	+ .1	— .3	+ .9	+1.3	+ .6	+2.6	+1.4	+1.3	+2.0	+ .7	+ .2
1930....	+ .8	+4.6	+3.6	0	+3.4	+2.5	+1.3	+3.8	+3.7	+1.7	+3.4	+1.6
Means..	62.2	62.3	63.0	63.9	65.4	67.1	68.1	68.7	68.9	67.4	65.7	64.3

Station: Olaa Mill

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—6.3	—10.2	—5.7	—8.0	—11.5	—10.9	—7.5	—5.6	— .6	—4.8	—3.7	—3.9
1906....	—4.9	—7.1	—1.4	—1.5	—2.1	— .2	—3.7	—4.1	—3.6	—1.5	—2.9	—2.5
1907....	— .5	0	— .6	—1.7	+ .3	— .6	—1.4	—1.6	+1.2	+1.6	+1.3	+1.3
1908....	+ .2	+1.3	+1.1	+ .2	— .3	— .9	+ .2	— .1	+ .6	+ .7	+ .5	— .3
1909....	—1.2	+ .6	—1.4	+ .1	— .8	+ .5	+ .7	— .4	—1.8	+ .9	+ .6	+ .2
1910....	+ .9	— .7	+ .2	+ .4	+ .3	— .2	— .2	+ .4	— .1	— .6	+ .7	— .4
1911....	+ .8	+1.1	+ .7	+1.8	— .2	+ .8	+1.2	+1.6	+1.0	0	— .4	—1.4
1912....	— .9	+1.2	+ .1	— .8	+ .1	+ .3	+ .7	+ .1	+1.2	+ .3	+ .3	+1.0
1913....	+1.5	+ .1	+ .6	— .8	+ .1	+ .7	+1.2	+1.2	0	+1.7	+ .9	+ .9
1914....	+ .2	+1.1	+ .6	+1.9	+1.7	+1.2	+2.9	+2.4	+3.0	+ .9	+ .9	— .8
1915....	— .1	+ .8	+ .6	— .1	+2.6	+1.6	+ .7	+ .6	+1.2	+ .7	+ .8	— .1
1916....	+3.0	+2.3	+2.3	+1.8	+1.3	+ .5	—1.0	—1.5	—1.5	+ .3	— .9	0
1917....	+ .5	+ .6	+1.7	— .6	+ .6	+ .5	— .7	—1.0	—1.2	— .3	+ .2	+ .3
1918....	+1.5	+1.3	— .1	+2.1	+1.4	+ .9	+2.2	+1.1	+ .5	+1.3	+2.2	+1.8
1919....	+ .8	+ .5	+ .1	+ .2	+ .3	+1.5	+ .1	+1.0	— .3	— .6	— .4	+1.0
1920....	+1.6	+ .9	— .4	+ .3	+2.1	+1.5	+1.7	+1.8	+ .3	0	0	+1.2
1921....	+2.7	+2.1	+1.1	+1.5	+1.7	+1.5	+1.1	+1.1	+ .8	— .1	— .1	+ .7
1922....	0	+ .6	+1.1	+2.0	— .1	+ .2	+ .3	+ .3	— .5	— .4	+ .1	— .9
1923....	+1.4	+1.5	+ .6	+ .9	+ .4	— .8	+ .2	— .3	+ .9	+ .7	— .2	+ .7
1924....	—1.9	+2.0	— .7	+1.8	— .6	— .9	—1.4	— .8	—2.1	— .8	— .9	— .5
1925....	— .7	0	—1.0	—1.7	— .4	—1.0	— .8	— .5	— .8	—1.0	— .1	— .2
1926....	—1.0	+ .1	—2.6	—2.6	— .6	— .2	— .2	— .7	— .7	— .2	—1.7	—1.3
1927....	— .1	—1.1	— .4	— .2	— .8	—1.0	—1.3	—1.3	—2.5	—1.5	—1.2	—1.1
1928....	—1.2	—2.6	—2.2	+ .2	+2.2	+1.0	+1.7	+1.6	+ .2	+ .8	+1.8	+ .8
1929....	+1.4	+1.5	+2.7	+1.9	+2.0	+1.4	+1.9	+1.0	+1.3	+1.3	+1.0	+1.5
1930....	+1.6	+1.9	+2.1	+1.3	+ .9	+1.7	+2.0	+3.2	+3.1	+1.7	+2.1	+1.1
Means..	60.2	59.9	60.9	62.2	63.1	64.3	65.3	65.9	65.6	64.8	63.3	62.2

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MINIMUM TEMPERATURE

Station. Ookala

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—2.2	—1.5	—1.2	— .9	—1.0	—1.2	— .4	— .1	—1.1	—2.3	....	—1.7
1906....	—1.9	—1.7	—2.9	0	+ .2	+ .8	+1.1	+1.5	+1.4	+1.1	+ .8	+ .7
1907....	+1.0	— .4	— .6	—1.3	0	+ .8	— .1	+ .2	+ .8	— .2	— .2	+ .4
1908....	—1.2	— .6	+ .3	—1.2	—1.1	— .9	— .3	— .5	—1.7	—1.0	—1.3	— .3
1909....	+ .2	—1.3	—1.7	—1.7	—3.0	—4.5	—5.4	—3.1	—3.0	—1.7	—1.7	—2.3
1910....	....	— .5	— .1	0	— .9	....	....	....	....	....	....	—1.2
1911....	—1.2	— .5	—1.0	+ .9	— .3	— .1	— .3	+ .3	—1.6	—2.2	—1.1	—1.3
1912....	—1.9	— .5	—2.4	....	— .7	+ .2	0	+ .8	— .5	0	—1.1	— .8
1913....	+ .1	— .3	— .4	—1.0	— .7	+ .5	+ .6	+1.1	— .4	+1.5	+ .6	— .8
1914....	—1.6	— .1	— .4	+ .2	+ .5	+1.1	+2.0	+2.2	+1.6	+ .2	+ .3	— .9
1915....	— .2	—2.0	— .8	+ .2	+2.0	+1.4	+ .8	+1.6	+ .6	+ .1	— .2	0
1916....	+ .8	+1.4	+1.7	+1.3	+1.2	+ .1	— .6	—2.3	—1.7	— .2	— .3	+1.7
1917....	+2.7	— .8	— .4	+ .2	— .4	+ .3	— .5	+ .5	— .8	— .7	— .6	0
1918....	— .4	— .6	—1.6	— .5	— .5	— .5	— .1	+ .6	+ .4	+ .8	— .2	— .3
1919....	+1.4	+ .2	— .3	+ .3	+5.5	+8.6	+1.5	+ .1	—1.5	+ .3	+1.5	+2.8
1920....	—1.0	+ .7	+1.1	—1.5	—1.7	+ .2	0	+ .4	— .4	— .3	— .8	+ .3
1921....	+ .6	+1.2	+ .4	+ .5	0	+1.4	+1.4	+ .3	— .6	0	—1.8	— .7
1922....	— .2	+3.7	+5.9	+3.0	+ .1	—7.3	+2.4	— .1	+3.3	+4.4	+4.9	+2.1
1923....	+1.2	+1.8	+1.3	+ .6	+2.6	—2.1	—1.8	—2.1	+5.2	— .6	— .7	— .4
1924....	—3.4	— .7	—2.7	— .7	— .6	— .3	— .6	— .1	— .9	— .8	— .1	+ .2
1925....	— .2	0	+ .6	— .3	— .1	+ .1	— .4	+1.1	— .4	— .1	—1.3	— .9
1926....	+2.1	+1.7	+ .7	—1.4	—4.4	—2.8	—5.3	—5.4	+ .8	— .9	— .9	— .2
1927....	— .4	+1.4	+ .7	+ .9	+1.7	+1.3	+1.5	+ .6	0	+ .9	+ .5	+ .6
1928....	+ .5	—1.4	+1.0	+ .7	+ .9	+ .5	+ .9	+ .8	+ .2	—2.7	+ .6	— .1
1929....	0	+ .2	+2.3	+1.6	+2.1	+2.0	+3.0	+2.3	+2.2	+1.9	+ .7	+1.1
1930....	+4.7	+1.7	+ .5	+ .1	— .6	+1.1	+1.3	....	....	+2.3	+2.0	+ .9
Means..	62.7	62.3	62.9	63.6	64.8	65.8	66.4	67.2	68.0	67.0	65.8	64.4

Station: Pahala

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— .8	— .6	— .2	— .7	+ .2	— .1	+ .6	+1.4	+ .4	+ .3	+ .4	—2.6
1906....	— .4	+ .1	—1.6	— .1	+ .9	+ .7	+1.3	+1.6	+ .3	+1.1	+ .5	+ .8
1907....	+3.2	+1.0	0	—1.8	— .4	+ .4	— .6	+1.2	+ .1	— .6	— .7	—1.1
1908....	—2.8	— .4	+ .2	—1.4	— .7	—1.6	—2.0	— .9	— .5	— .9	—2.2	—1.9
1909....	—2.2	— .3	—1.9	— .8	—2.2	— .8	— .9	—2.2	—1.9	—1.3	—2.5	—1.9
1910....	—2.2	—3.0	—2.0	—2.2	—2.8	—1.6	—2.1	—1.5	—1.6	—1.6	+ .6	— .3
1911....	+ .7	+ .8	+ .8	+3.0	— .9	0	+ .4	+1.0	+ .6	— .7	— .3	— .3
1912....	—1.8	+ .2	—2.6	—1.5	—1.1	— .2	0	+ .5	+ .6	+1.3	0	+1.3
1913....	+ .8	— .7	— .3	—1.3	—1.3	+ .3	— .1	+ .1	+ .2	+1.7	+ .5	— .3
1914....	—2.7	—1.5	— .7	+1.4	+1.4	— .1	— .3	+1.6	+1.4	— .7	— .7	—2.0
1915....	—1.1	—2.7	—1.2	— .6	+ .8	+ .6	0	— .1	— .1	—1.0	—1.1	— .1
1916....	+2.5	+1.8	+5.1	+1.0	+ .2	— .9	+ .2	—2.2	— .7	+ .3	—1.5	—2.7
1917....	—1.3	—2.5	—4.3	—3.3	— .1	—1.9	—2.3	—2.9	—3.0	—1.5	—1.3	— .8
1918....	— .8	— .9	—1.5	+ .5	— .1	+ .3	+ .2	— .5	—1.2	— .4	+ .1	— .8
1919....	—2.7	—1.0	— .8	— .2	—1.1	— .2	—2.2	— .4	—1.1	—1.1	—1.6	— .6
1920....	+1.7	— .7	—1.7	—3.3	—2.6	—3.2	—3.6	—5.2	—6.6	—5.3	—2.9	+ .3
1921....	+2.8	+1.1	— .1	— .2	— .8	—1.0	— .6	0	+ .9	+ .7	+ .2	+1.8
1922....	+1.0	— .5	+1.2	+1.4	+ .4	+ .4	+ .3	—5.6	+1.7	+ .9	+1.0	+ .2
1923....	— .5	+1.6	+1.4	+2.1	+ .4	+ .2	+1.1	+ .4	+1.1	+ .7	+1.2	+2.5
1924....	—1.2	+2.1	+1.4	+2.5	+1.0	— .3	— .8	+ .1	— .1	— .6	0	— .4
1925....	+ .7	....	....	....	+1.0	+1.3	+1.1	+2.3	+1.1	+1.2	+1.3	+2.5
1926....	+1.4	+2.3	+ .9	— .5	+1.2	+2.8	+1.9	+2.6	+1.2	+2.1	+ .5	+2.3
1927....	+2.2	+2.0	+3.3	+1.2	+2.4	+2.0	+2.1	+1.7	+ .9	0	+2.3	+1.8
1928....	+1.2	— .3	+ .6	+1.1	+1.4	+ .3	+1.9	+ .6	+ .9	+ .6	+2.3	+ .4
1929....	+ .4	+ .1	+2.1	+1.6	+1.5	+1.3	+1.3	+2.2	+2.4	+2.4	+1.8	+2.4
1930....	+3.0	+2.5	+3.0	+1.4	+1.1	+2.3	+2.4	+4.2	+3.7	+2.5	+3.1	+ .4
Means..	58.8	58.5	59.2	60.4	61.3	62.1	63.1	63.5	63.8	63.2	62.0	60.8

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MINIMUM TEMPERATURE

Station: Pepeekeo

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	+ .3	+ .4	+ .8	— .5	0	+ .2	+1.2	+1.8	+1.1	+ .8	+ .7	— .1
1906....	+ .5	+ .3	—1.5	+ .7	+ .7	+1.0	+ .2	+ .6	0	+ .5	+ .6	+1.7
1907....	+2.9	+1.7	+ .9	— .2	+1.7	....	+2.8	+1.8	+1.9	+1.5	+ .7	+1.5
1908....	— .4	— .2	+1.4	— .8	—1.7	—3.4	—5.1	—5.8	—4.0	—3.6	—2.5	—2.0
1909....	— .4	+1.2	+ .8	+ .2	— .6	+ .4	— .3	—1.0	— .9	+ .5	+ .9	+ .4
1910....	— .4	—1.1	0	—1.0	— .1	— .4	— .7	+ .1	— .3	— .7	+ .2	— .4
1911....	— .6	+ .8	— .7	+1.0	+ .1	+ .5	+ .3	+ .4	— .6	—1.0	— .5	— .9
1912....	—1.2	0	—2.0	— .6	—1.3	— .7	— .4	— .2	— .4	+ .2	— .1	— .1
1913....	+ .5	— .3	— .6	—1.4	—1.5	— .7	— .9	+ .8	+ .1	+1.1	+ .7	0
1914....	—1.5	— .3	0	+ .8	+ .5	+1.4	+2.0	+1.9.	+1.9	+ .4	+ .5	— .9
1915....	— .7	—1.4	— .2	0	+1.9	+1.8	+ .8	+ .9	+ .9	+ .5	0	+ .6
1916....	+ .9	+ .6	+1.7	+ .5	—1.1	— .9	....	—2.6	....	—1.8	—1.7	— .5
1917....	—1.1	—1.4	— .5	—1.3	—1.7	—2.4	—1.1	— .4	— .7	—1.7	— .8	— .4
1918....	— .7	—2.2	—1.7	—1.0	— .9	— .2	— .6	—1.4	+1.3	+1.1	+ .7	— .6
1919....	— .3	+1.7	— .5	+ .4	— .6	+ .1	— .3	— .2	— .3	+ .6	— .1	0
1920....	+1.2	+1.3	+ .1	+ .6	+1.3	— .5	—2.6	—1.4	—1.0	—1.4	—2.0	—1.3
1921....	— .1	+2.2	+1.9	+ .6	+ .4	+ .6	+ .1	—1.7	—1.5	+ .1	+ .5	— .7
1922....	+ .3	+ .1	+ .4	+ .8	— .7	—1.6	— .8	— .8	—1.8	+ .3	—1.6	—1.0
1923....	—1.6	—3.5	—1.5	— .8	+ .7	+ .5	+ .7	+ .9	+1.3	+1.5	+ .8	+1.3
1924....	—1.1	+1.7	0	+1.5	+ .5	+ .3	— .3	+ .2	— .3	+ .2	+ .5	+ .9
1925....	+ .3	+ .3	— .1	— .6	+ .6	+ .2	+ .7	+ .4	+ .5	+ .5	— .5	+ .5
1926....	+ .4	—3.1	—3.0	—1.7	— .4	+ .9	+ .5	+1.0	+1.0	+1.3	+ .5	+1.3
1927....	+1.2	+ .9	+1.9	+1.5	+ .9	+1.9	+ .9	+ .2	— .4	— .2	+ .6	+ .6
1928....	0	—1.1	— .2	+ .4	— .1	— .6	+ .6	+2.1	+ .3	— .7	+ .3	— .7
1929....	+ .9	+ .4	+1.2	+ .6	+1.2	+1.5	+1.2	+ .5	+ .4	+ .2	+ .4	+ .3
1930....	+ .7	+1.6	+1.0	— .1	— .5	+ .3	+ .4	+1.3	+2.2	+ .9	+2.3	+1.7
Means..	63.2	63.1	63.5	64.8	65.8	66.5	67.8	68.4	68.4	67.4	66 3	64.7

Station: Eleele

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1917....	0	— .2	+2.0	+1.3	+ .6	+ .3	— .9	— .8	....	—2.2	—2.1	—1.3
1918....	— .4	— .3	—1.8	—2.0	—2.3	—1.8	....	—1.4	—1.1	+ .1	—1.1	— .8
1919....	—2.8	— .3	—1.7	—1.3	—2.8	— .5	—1.5	—1.5	—2.8	—1.8	—1.3	—1.5
1920....	—2.2	—1.9	—1.9	—1.5	—2.1	—1.2	—2.0	—1.0	—1.9	— .6	+1.3	— .4
1921....	+1.0	— .1	—2.0	— .4	—2.3	—1.0	—2.1	—2.7	—2.1	—2.7	—2.3	— .9
1922....	— .8	—1.4	—1.6	—1.4	—3.5	—2.7	—2.4	—2.0	—1.7	—1.8	—3.0	—2.3
1923....	+ .4	—3.5	—2.1	—1.9	—2.0	—3.0	—2.2	—2.3	—2.1	—1.1	—1.6	—1.4
1924....	—2.5	—1.2	—2.7	—2.1	—3.0	—2.2	—1.7	....	— .6	— .9	—1.3	— .4
1925....	+ .7	+1.2	—2.9	+ .7	+2.0	+3.5	+3.9	+1.4	+2.2	+2.2	+3.1	+4.6
1926....	+4.3	+4.3	+4.5	+1.0	+ .8	+3.8	+4.8	+4.6	+4.4	+2.5	+4.1	....
1927....	....	....	+4.0	+1.1	+1.5	+1.5	+ .9	+1.4	+1.2	+2.4	+2.7	+3.0
1928....	+3.2	+ .2	+3.0	+3.2	+ .6	+ .2	+1.1	+ .5	+ .7	+1.7	+ .8	+1.4
1929....	— .9	+ .5	+2.0	+2.3	+1.2	+1.7	+2.0	+1.9	+1.8	+1.8	— .6	— .6
1930....	— .2	+2.2	+1.0	+ .6	+ .8	+1.2	+ .5	+2.2	+1.8	+ .5	+ .7	+1.0
Means..	62.0	62.3	62.7	64.2	66.9	68.5	69.8	70.0	69.8	68.6	66.7	64.0

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MINIMUM TEMPERATURE

Station: Kealia

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—3.0	—2.4	— .6	+ .4	+ .3	+ .1	+ .8	+1.2	+ .7	+ .9	+1.5	+1.2
1906....	+ .1	—1.2	—1.0	+ .8	— .1	+1.3	+1.5	+ .8	+ .1	+1.5	+ .5	— .2
1907....	+1.7	....	+ .4	—1.5	—1.8	0	— .6	— .1	....	—1.0	— .8	+ .4
1908....	....	....	— .9	—1.2	+2.2	+ .9	+ .8	+ .2	+1.0	+ .2	—1.8	+3.5
1909....	—1.4	+ .6	+ .4	—1.6	0	— .8	— .9	—1.2	— .9	—1.1	—2.3	— .8
1910....	+ .5	— .7	— .3	+ .5	—2.6	—2.5	—2.1	—1.7	—1.7	—1.8	—1.0	—2.1
1911....	+1.3	....	—1.5	— .3	+ .6	+ .5	— .7	+1.5	0	—1.2	+ .9	+1.5
1912....	— .7	—1.0	— .3	+ .9	+ .1	— .9	—1.2	—1.8	— .4	+2.2	....	+3.0
1913....	—1.0	—2.6	—1.5	— .3	—1.9	—1.3	—1.1	— .8	— .8	—1.2	+ .5	—1.9
1914....	—2.6	....	—4.2	—3.1	—2.0	—1.6	—1.2	— .5	+ .2	+ .2	—3.0	—5.7
1915....	—4.9	—2.1	—6.2	—4.4	—3.9	—3.4	—2.5	—3.7	—4.4	—3.0	—2.3	—3.9
1916....	—5.3	—3.1	—4.6	—5.7	—5.8	—6.6	—7.3	—8.8	—7.3	—6.5	—4.6	—5.9
1917....	—6.2	—2.9	+1.5	+1.5	+ .4	+1.6	— .8	— .2	— .4	— .7	+ .8	+ .7
1918....	+ .8	+2.9	+1.0	—1.6	+ .4	+ .2	+ .7	+ .6	+ .6	+2.2	— .3	+2.4
1919....	+ .5	—1.7	+1.3	+1.9	+1.5	+1.7	+1.3	+ .8	— .2	+2.1	+2.3	—2.0
1920....	+1.6	+ .9	....	— .1	—1.8	+ .9	+ .8	+1.3	+1.7	+1.1	+1.2	+2.3
1921....	+4.5	+1.4	— .3	+2.5	—1.0	+1.1	+1.5	— .1	+1.0	—1.5	+ .5	+1.7
1922....	+2.2	+2.5	+1.6	+1.3	+ .9	— .3	+ .8	+1.3	+ .8	+ .3	+ .7	— .9
1923....	+3.8	—1.5	— .2	+ .8	+1.6	+ .4	+2.0	+ .4	+1.9	+1.8	+1.0	+1.8
1924....	—1.0	+1.8	+1.0	— .2	— .2	+ .9	+1.5	+1.0	+ .7	+1.7	— .1	—1.3
1925....	+2.8	+2.4	+2.0	+2.3	+1.6	+1.7	0	+1.3	— .2	—1.0	+2.3	+ .2
1926....	+1.1	+1.7	+2.1	—1.4	+2.3	— .6	+2.3	+1.8	+2.1	0	+ .7	+3.4
1927....	+3.7	— .3	+3.2	+1.3	+2.6	+1.6	+1.5	+1.1	+ .5	+2.7	+3.0	+1.7
1928....	+3.9	+1.1	+2.1	+2.9	+1.4	+1.5	+1.0	+1.2	+1.9	+1.7	0	+2.2
1929....	— .2	+2.3	+3.3	+3.2	+1.8	+1.4	+1.9	+1.7	+2.1	+ .9	—1.1	—1.9
1930....	—1.8	+2.7	+ .4	+1.1	+2.9	+1.4	+1.8	+3.4	+2.0	+ .5	+ .8	+1.8
Means..	62.5	62.1	63.8	65.9	67.9	70.2	71.4	72.0	71.5	70.0	67.4	65.1

Station: Kilauea

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—3.3	—3.1	—2.0	— .6	— .3	— .9	— .7	+ .2	0	— .2	+ .5	+ .1
1906....	— .7	—2.3	—3.0	+ .7	— .2	+ .2	0	— .3	+ .2	+1.0	+ .4	+ .7
1907....	+ .6	+ .9	— .1	—1.8	— .8	0	— .4	— .2	— .3	—1.3	—1.0	— .1
1908....	—1.3	— .2	+ .4	— .5	—1.4	—1.2	— .4	—1.3	— .3	—1.1	—1.9	+1.1
1909....	+ .5	— .4	+ .3	— .9	— .2	+ .8	0	— .8	— .8	+ .9	—2.5	+ .4
1910....	+ .7	+ .6	+ .7	+ .8	—1.0	—1.1	— .9	— .5	— .8	—1.5	+ .5	— .6
1911....	+1.4	+ .3	0	+ .6	+ .4	+ .6	— .1	+ .8	— .1	—1.0	+ .2	+ .5
1912....	+ .1	+ .7	— .9	— .3	— .6	— .6	— .5	— .7	0	+1.2	— .3	+2.0
1913....	— .1	— .3	— .9	+ .7	0	+ .2	+ .8	+ .6	+ .3	— .2	+1.8	—1.7
1914....	— .4	—1.4	—2.1	—1.4	— .1	+ .5	+ .8	+1.5	+1.3	+ .6	— .5	—3.8
1915....	—3.5	— .3	—1.8	—1.2	+ .9	+1.2	+ .9	+ .6	+ .4	+1.1	+1.6	+1.6
1916....	— .1	+1.3	+1.0	+1.7	+1.5	+ .2	— .1	—2.1	— .8	— .3	+1.1	+ .8
1917....	+ .8	—3.0	+1.6	+ .7	+ .6	+ .5	— .4	— .9	— .6	—1.2	+ .8	+1.9
1918....	0	+1.1	—1.2	— .2	0	— .2	+ .5	+ .3	— .2	+1.9	0	+1.0
1919....	— .6	+1.5	+ .9	— .2	— .4	+ .7	+ .5	— .2	—1.5	+ .4	+ .3	—1.5
1920....	+ .6	+ .8	+ .5	+ .1	+ .5	+ .5	+ .9	+1.3	+ .3	+ .3	— .1	+ .7
1921....	+2.8	+1.3	— .1	+1.5	+ .1	+1.3	+1.6	+2.7	+ .7	—1.0	+ .1	+ .7
1922....	+1.6	+ .7	+1.0	+ .6	0	— .1	+ .1	— .8	+ .4	+ .2	— .5	—1.5
1923....	+1.8	—1.6	+ .1	+ .1	+ .9	— .4	+ .9	— .3	+1.3	+ .2	— .5	+2.1
1924....	—1.0	+ .3	0	—1.1	—1.4	— .2	— .5	— .4	—1.1	+ .1	— .4	—1.9
1925....	+1.9	+2.4	+ .8	+ .8	+ .4	— .6	—2.0	— .5	—1.5	—1.0	+ .2	—1.3
1926....	—2.2	+ .1	+ .3	—2.8	— .4	—2.8	—1.4	— .1	+ .8	—1.0	—1.2	+ .3
1927....	+1.9	— .7	+2.3	— .1	+ .8	+ .9	0	— .3	— .6	+1.2	+1.9	+ .2
1928....	+ .8	— .5	+ .3	+ .8	— .2	— .9	— .9	— .6	0	+ .1	— .3	— .1
1929....	—1.2	+ .2	+1.5	+ .8	+ .7	+ .2	+ .2	— .2	+ .7	+ .3	—1.7	—1.8
1930....	—1.4	+1.2	— .1	— .2	+1.0	+ .7	+ .5	+1.3	+1.3	+ .1	+ .5	....
Means..	61.7	61.5	62.5	64.4	65.7	68.0	69.0	69.9	69.2	68.0	65.9	63.8

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MINIMUM TEMPERATURE

Station: Koloa

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—4.7	—2.3	—5.8	—8.1	—5.5	— .9	— .7	0	+ .2	+ .2	+ .3	+1.2
1906....	—1.2	—1.6	—3.9	+ .2	+ .2	+1.5	+ .4	— .1	+ .1	+ .9	+ .4	+ .1
1907....	+1.1	+1.2	0	—2.4	—1.5	— .3	—1.5	— .7	— .1	—1.0	—1.5	— .2
1908....	— .6	— .1	— .3	— .3	+1.0	— .5	— .4	—1.1	0	— .5	—1.9	+1.1
1909....	— .1	+ .1	+ .4	—1.6	— .4	— .3	— .8	—1.9	—1.2	—1.9	—2.5	— .7
1910....	+1.7	+ .1	+1.5	+ .9	—1.4	—1.3	— .7	— .7	— .3	—1.3	+ .8	—1.9
1911....	+1.0	— .1	— .6	+ .9	0	— .2	— .7	+ .3	— .5	—2.0	+1.0	+ .1
1912....	— .5	—1.4	— .8	+ .2	+ .2	—1.1	— .1	— .2	— .1	+1.8	+ .4	+2.8
1913....	— .1	—1.4	— .4	+1.4	— .2	+ .2	+ .7	+1.0	+ .1	— .2	+2.5	—2.2
1914....	—1.6	—2.2	—3.3	—1.2	— .8	+ .8	+1.0	+1.0	+1.9	+1.4	— .1	—3.6
1915....	—1.6	+ .1	—1.9	—1.1	+ .2	— .3	+ .6	+ .3	— .2	+ .6	+2.3	+1.5
1916....	+ .7	+1.8	+1.7	+2.2	+ .8	— .3	— .2	—2.0	— .9	—1.3	+ .1	+ .2
1917....	—1.3	—3.2	+2.3	+1.7	+ .4	+1.1	— .4	— .2	— .4	—1.3	+ .2	—1.0
1918....	+ .8	+ .8	+ .5	— .3	— .1	— .1	+ .5	+ .5	+ .5	+1.7	+1.0	+2.2
1919....	— .7	+1.9	— .3	+ .6	+ .8	+ .7	+ .3	+ .4	—1.6	+ .8	0	—2.3
1920....	—1.5	+ .8	+ .4	+ .3	+ .1	+1.2	+ .8	0	— .2	+ .7	+ .4	+1.9
1921....	+3.6	+2.3	+ .6	+2.1	— .3	+1.2	+ .6	— .6	+ .1	—1.5	— .6	+ .6
1922....	+1.8	+1.2	+ .8	+ .8	— .3	—1.3	— .7	—1.0	— .8	— .6	—1.5	—2.3
1923....	+1.8	—2.5	+ .1	+1.2	+ .9	+ .3	+ .2	+ .4	+1.2	+1.2	+ .5	+1.0
1924....	—2.3	+1.0	+ .8	0	— .4	+ .1	— .2	— .2	+ .8	+1.0	— .5	— .9
1925....	+2.2	+1.0	+ .4	+ .5	+ .4	+ .5	— .6	+ .5	— .4	—1.3	+1.7	+ .2
1926....	+ .5	+ .2	— .1	—3.0	+1.2	—1.8	+1.0	+ .4	+ .5	— .4	— .7	+1.0
1927....	+2.5	—1.3	+2.1	+ .5	+1.1	0	— .2	— .4	—1.2	+ .7	+1.7	+1.0
1928....	+2.2	— .1	+1.6	+1.9	+ .5	— .2	— .3	0	— .1	+ .6	— .6	+1.9
1929....	—1.0	+1.6	+2.7	+1.7	+1.1	+1.1	+1.5	+ .6	+ .7	+ .9	—1.6	—2.3
1930....	—2.6	+1.8	+2.0	— .5	+1.4	+ .4	+ .9	+2.0	+1.7	+ .7	—1.6	+1.4
Means..	61.7	61.7	62.8	64.8	66.8	69.1	70.2	70.9	70.4	68.8	66.3	64.2

Station: Lihue

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—5.0	—2.1	—1.5	— .2	— .2	— .1	— .1	+ .7	+ .1	+ .7	+1.0	+ .3
1906....	— .9	—2.5	—4.8	+ .2	— .1	+ .8	— .5	— .2	— .1	+ .7	+ .5	+1.1
1907....	+1.0	+2.1	— .3	—3.4	—2.1	— .5	—1.0	— .1	— .5	— .9	—2.5	— .9
1908....	—3.1	—2.0	+1.1	+ .3	+1.3	0	— .2	— .7	0	— .9	—3.7	+1.1
1909....	— .8	— .5	+ .1	—3.8	—1.7	—2.0	—6.2	—5.5	—2.7	—1.3	—2.6	— .1
1910....	— .2	—1.2	— .1	— .4	—2.8	—2.8	—2.2	—1.8	—1.8	—1.7	+ .9	—3.6
1911....	+1.7	+ .5	— .8	+ .2	— .7	+ .4	— .7	+1.0	+ .4	—1.0	+ .6	+ .7
1912....	— .6	+ .1	+ .3	+1.4	+ .1	— .4	+ .5	— .2	+ .3	—1.7	—2.9	+3.1
1913....	— .4	— .9	— .4	+1.0	— .2	+ .9	+1.0	+1.0	0	— .4	+2.3	—2.4
1914....	— .3	—2.2	—2.5	—1.7	— .9	+ .1	+ .4	+ .4	+ .8	+ .5	—1.1	—4.0
1915....	—1.9	0	—3.9	—1.1	— .4	—1.8	0	— .5	—1.1	— .5	+1.4	— .9
1916....	....	— .8	+2.0	+1.2	+1.5	+ .4	0	—1.6	+ .2	+ .9	+2.3	+1.7
1917....	— .1	—3.0	+1.2	+ .5	— .6	+1.6	— .1	+ .5	—1.2	—1.6	+ .8	—1.0
1918....	+ .9	+1.7	0	—1.2	— .2	— .3	+ .8	+ .4	— .3	+2.3	+ .4	+1.4
1919....	— .8	+2.2	— .1	+1.0	— .1	+ .8	+ .5	+ .3	— .8	+ .8	+ .2	—2.8
1920....	— .8	+ .6	0	— .6	— .6	+ .4	+ .3	+1.0	+ .7	+1.0	— .3	+1.7
1921....	+3.8	+2.7	— .3	+1.8	— .4	+1.3	+1.4	— .5	+ .2	—1.5	— .7	+1.1
1922....	+1.6	+2.0	+ .1	+ .6	— .2	—1.0	— .4	— .4	+ .3	— .2	— .4	—2.0
1923....	+3.1	—2.9	— .9	+ .4	+ .4	— .3	+ .8	— .2	+1.0	+1.6	+ .3	+1.4
1924....	—2.9	+ .6	— .5	—1.1	— .9	—1.0	— .3	— .1	+ .4	+1.3	— .7	— .3
1925....	+1.6	+1.5	+ .5	+1.1	+ .9	+1.0	— .5	+ .7	— .7	—1.5	+2.6	+ .4
1926....	+ .6	+1.0	+1.4	—2.2	+1.6	—1.0	+1.1	+1.1	+1.1	— .5	— .1	+2.2
1927....	+3.2	— .2	+2.9	+ .3	+2.3	+ .5	+1.2	+ .9	— .4	+2.4	+2.9	+ .7
1928....	+3.2	0	+1.7	+2.8	+1.0	+ .5	+1.4	+ .9	+ .9	+1.6	+ .3	+1.9
1929....	— .5	+2.2	+2.7	+1.9	+ .9	+1.2	+1.6	+1.4	+ .5	+ .5	—1.7	—2.7
1930....	—2.8	+2.1	+ .9	— .2	+2.4	+1.4	+1.3	+2.7	+1.5	+ .5	+ .3	+ .9
Means..	60.6	60.1	62.0	64.0	66.1	68.4	69.5	70.1	69.6	67.5	65.0	63.1

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MINIMUM TEMPERATURE

Station: Makaweli

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—4.7	—1.5	—2.3	—1.0	— .3	— .3	— .6	+1.0	+ .5	+ .1	+1.4	— .5
1906....	+ .5	+ .1	—2.6	+1.0	+1.4	+2.3	+ .3	+1.7	+1.3	+2.3	+ .9	+1.4
1907....	+2.7	+2.2	+ .9	—1.6	— .7	+ .3	— .3	+1.2	+1.0	— .1	0	+ .5
1908....	+1.9	+1.5	+1.6	+ .6	+1.1	— .1	—1.1	— .6	— .3	— .3	—2.2	0
1909....	+ .4	+1.8	+1.3	+ .4	— .3	+ .3	— .5	—1.0	—1.1	+ .1	0	+ .1
1910....	+ .3	—1.7	+ .7	+1.1	—1.3	—1.1	—1.1	— .5	+ .5	— .1	+ .7	—1.1
1911....	+1.2	— .2	+ .2	+ .9	—1.1	— .7	—2.4	+ .7	— .2	— .7	+1.5	+ .6
1912....	+2.0	— .2	— .8	+ .3	+1.0	—1.1	— .7	—3.5	—4.9	—4.4	— .5	+2.8
1913....	+1.7	— .2	— .3	+1.6	+ .4	+ .6	+ .8	+1.1	+1.4	+1.6	+2.6	— .6
1914....	—1.7	— .6	— .9	+ .2	— .5	+ .8	+1.5	+2.1	+1.5	+ .6	+ .4	—3.1
1915....	—1.7	—1.9	— .2	+ .2	+ .8	+1.1	+1.5	+1.7	+1.3	+1.7	+1.7	+1.0
1916....	+1.1	+1.9	+1.1	+1.5	+ .9	+ .4	0	—1.9	— .2	+ .5	+ .8	+ .7
1917....	+ .4	— .6	+2.7	— .2	— .2	+1.9	— .3	0	+1.0	+ .3	+ .3	+ .4
1918....	+ .5	+1.5	— .1	0	+ .1	+ .4	+ .8	+ .9	+1.4	+2.4	— .2	+ .7
1919....	—1.3	+1.5	+ .5	+ .9	+ .1	+ .4	— .1	+ .7	— .7	+ .5	+ .6	— .8
1920....	— .6	0	— .5	—1.0	+ .4	+1.0	+ .7	+1.0	0	+ .2	— .7	+1.1
1921....	+2.4	+1.8	+ .1	+1.2	+ .2	+1.1	+ .6	—1.4	— .2	—1.9	—1.8	—1.0
1922....	— .1	— .9	— .6	— .3	—2.1	—1.2	—1.1	— .9	— .8	—1.5	—3.2	—2.8
1923....	+ .4	—2.5	— .7	— .1	+1.4	— .7	+ .8	—2.8	— .2	+1.9	+ .7	+ .3
1924....	—1.0	+1.0	0	+ .4	— .1	—1.1	+1.0	+1.1	+1.3	+ .3	+ .1	— .1
1925....	+1.3	+1.1	+ .3	+ .5	— .5	+ .7	+ .9	+1.4	— .9	— .5	+ .9	+1.0
1926....	+ .3	— .1	+ .5	—2.5	+1.1	— .7	+ .2	+ .6	+ .2	— .4	—1.0	+3.9
1927....	+1.0	—1.5	+ .9	— .8	+ .9	— .5	— .1	—1.4	— .3	+ .6	+ .8	— .2
1928....	+ .2	—2.1	+ .5	+ .4	—1.3	—1.4	— .7	—1.0	— .9	— .1	— .6	— .8
1929....	—2.8	—1.3	+ .1	— .2	—1.4	— .5	0	0	+ .3	— .6	—2.4	—3.7
1930....	—3.6	+ .1	—1.9	—3.0	— .8	—1.5	—1.1	+ .5	— .3	—1.8	—1.1	....
Means..	62.3	62.4	63.1	64.4	66.4	68.4	69.6	70.0	69.7	68.4	66.4	64.3

Station: Hana

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	....	....	....	....	....	....	....	....	....	....	....	....
1906....	....	....	....	....	....	....	....	....	....	....	....	....
1907....	....	....	....	....	0	+1.9	+ .8	— .7	+ .7	— .6	+ .3	+1.4
1908....	+1.2	+4.4	+3.5	+3.5	+2.2	+ .4	— .2	+ .7	+ .5	+ .3	—1.3	+1.1
1909....	+2.0	+ .8	+ .3	+ .6	0	+ .3	— .3	—1.2	—1.7	— .7	+1.2	+1.4
1910....	0	—2.1	+ .1	— .8	—1.6	— .9	— .8	— .8	— .7	— .7	+ .5	—1.4
1911....	— .3	+ .7	—1.2	+ .1	— .1	+ .1	+ .3	— .4	— .9	—3.1	— .6	— .6
1912....	—1.7	— .6	—1.8	0	— .2	+ 3	— .2	0	+2.8	+1.5	+1.5	+3.0
1913....	+3.3	+1.1	+1.6	+ .9	+ .5	+1.3	+1.3	+1.0	+ .2	+1.6	+1.3	+ .4
1914....	— .2	+1.0	0	+ .1	— .4	+ .1	+ .4	+ .7	+ .7	— .3	+1.4	+ .5
1915....	+ .8	—1.1	+3.9	+2.6	—4.6	+1.4	+2.1	+1.5	— .9	—1.2	— .9	— .5
1916....	+1.7	+ .3	+1.3	+ .1	— .4	—2.4	— .2	....	....	....	....	— .8
1917....	0	—2.5	+1.4	+ .9	+ .6	+1.0	— .6	— .3	— .5	+ .5	— .6	+ .3
1918....	+1.1	— .1	—1.0	— .7	+ .4	—1.1	+ .5	+ .8	+1.2	+2.0	+1.6	+1.3
1919....	+ .5	+1.1	— .5	+1.0	— .1	+1.4	+ .2	+1.0	+ .1	+1.4	+1.2	+ .5
1920....	+1.0	+1.7	— .3	+ .2	+1.6	+1.5	+ .1	+1.1	+1.4	+ .9	+ .3	+ .9
1921....	+2.0	+3.9	+ .1	—2.7	—4.6	—3.1	—4.2	—4.3	—5.1	—4.7	—4.7	—2.5
1922....	—4.0	—5.2	—4.7	—4.1	—6.0	—4.6	—2.8	—4.6	—4.9	—1.2	—4.9	—3.4
1923....	—2.7	—4.3	—4.0	—4.0	—3.0	—4.0	—4.3	—3.3	—3.3	—4.3	—4.2	—3.9
1924....	—5.7	—3.2	—7.6	— .8	—2.3	—2.3	— .8	— .3	— .3	— .1	— .9	—2.1
1925....	— .7	— .3	—1.8	—1.6	—2.2	....	....	....	+1.6	+1.9	+1.8	....
1926....	....	....	+3.6	+ .2	+4.0	+2.7	+3.2	+3.9	+4.0	+2.9	+3.4	+2.9
1927....	+2.1	+1.0	+2.5	+ .3	+2.0	+1.7	+1.9	+ .6	+ .7	+ .7	+2.2	+ .9
1928....	+1.4	— .5	+1.3	+2.0	+1.3	+1.1	+ .7	+1.1	+ .9	+1.0	+1.0	— .4
1929....	— .6	+ .7	+2.8	+1.9	+1.5	+1.5	+1.8	+ .6	+1.6	+1.2	— .5	— .6
1930....	— .5	+2.5	+ .8	+ .1	+1.1	+1.0	+1.3	+3.2	+3.2	+1.6	+1.2	+1.6
Means..	64.5	64.5	64.9	66.3	67.5	68.6	69.6	70.1	70.2	69.5	67.9	66.4

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MINIMUM TEMPERATURE

Station: Kaanapali

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—2.8	—1.2	— .7	0	+ .3	—1.8	—6.9	—6.1	+1.3	+1.0	+1.3	— .1
1906....	+ .2	—2.4	—2.4	+ .2	+ .7	+1.2	+2.0	+1.6	+1.0	+1.6	+ .2	— .2
1907....	+2.0	+1.6	0	—1.7	—1.1	+ .3	+ .6	+1.1	+1.6	— .5	+ .3	—1.7
1908....	—1.1	+ .3	+ .2	— .4	—1.0	—2.6	—1.5	—1.8	— .6	—1.7	—2.4	— .4
1909....	—2.4	+ .7	+1.7	+ .5	+ .6	+ .7	+ .4	0	— .2	+ .1	— .1	— .2
1910....	0	— .4	+ .2	+ .1	—1.3	—1.4	—1.0	0	— .3	+ .3	+ .4	— .3
1911....	+ .3	+ .6	— .1	+ .5	— .3	+ .2	+1.7	+1.8	+2.1	— .7	+ .8	+1.2
1912....	— .4	+1.1	— .7	+ .1	— .8	—1.8	— .1	+ .9	+ .6	+1.8	+ .7	+1.7
1913....	+ .8	+1.0	+1.0	+2.3	—1.2	— .6	+ .7	+1.9	+ .8	+1.3	+2.9	+ .3
1914....	0	+ .6	— .2	0	+ .2	— .1	+1.8	+2.2	+2.1	+ .4	+1.1	+ .3
1915....	+ .4	— .1	—1.0	0	+ .9	....	....	....	....	....	....	+ .4
1916....	+1.5	+ .9	+1.5	+1.1	+ .3	— .3	— .2	—1.1	— .8	— .1	+ .8	+ .9
1917....	+ .3	— .1	+ .9	+ .5	— .6	+ .6	+ .8	+ .1	+ .6	+ .3	+1.5	+2.7
1918....	+2.2	+1.3	— .2	0	—1.0	— .1	+2.4	+1.2	+ .7	+2.1	+1.7	+ .9
1919....	— .1	+ .7	+1.3	+1.4	+ .6	+1.2	+2.3	+2.7	+1.6	+1.7	+ .9	+1.2
1920....	+1.4	+1.4	+ .9	+ .9	+ .5	+ .8	+1.0	+1.8	+1.2	+ .5	+ .8	+1.7
1921....	+4.2	+1.3	+ .8	+2.0	+ .8	+2.7	....	+1.3	+1.3	+1.4	+1.0	+2.2
1922....	+1.6	+1.9	+ .2	+ .4	—1.2	—1.0	— .2	— .1	— .4	+ .7	+ .7	— .2
1923....	+3.6	+1.2	+1.6	+ .9	+ .3	— .3	+1.1	+ .4	+ .8	+2.0	+1.5	+1.6
1924....	—1.5	+1.1	— .5	+1.3	— .8	— .8	+ .9	+ .5	+ .7	+1.0	— .6	+ .2
1925....	+1.0	+ .4	+1.4	+ .4	— .4	— .4	+ .7	+1.3	+ .1	+ .2	+ .9	0
1926....	— .7	0	+1.4	+ .4	+4.5	+1.8	+2.0	+1.3	—1.1	+ .2	+1.0	+ .2
1927....	+1.7	+1.0	+1.5	+3.7	+5.4	+4.7	+2.0	+1.7	+1.5	+3.0	....	+4.6
1928....	+ .3	—1.4	—1.5	—3.5	....	....	....	—1.9	—4.8	—5.9	—3.8	—4.5
1929....	—5.1	—6.4	....	—4.0	+1.4	+1.9	—6.2	—6.3	—6.4	—4.3	—6.2	—7.0
1930....	—7.7	—5.4	—6.3	—6.7	—7.6	—5.8	—3.7	—4.5	—4.3	—5.5	—4.6	—6.1
Means..	62.2	61.5	63.0	64.4	66.6	68.2	68.5	69.0	68.8	67.5	65.7	63.7

Station: Wailuku

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—4.9	—2.6	—1.7	— .6	— .7	—1.0	— .3	+ .4	—1.2	— .8	— .5	—1.1
1906....	—1.1	—1.5	—4.5	— .2	— .3	+ .9	+ .1	+ .1	— .2	+ .6	— .8	— .2
1907....	+ .5	+1.1	— .8	—2.7	—1.3	+ .2	— .2	+ .5	+ .2	— .1	— .2	+ .8
1908....	— .4	+1.1	+1.3	+ .2	+ .8	— .8	— .9	— .8	— .9	— .3	—1.4	+ .2
1909....	— .1	— .5	0	—1.7	0	0	—1.2	—2.1	—1.7	— .6	—1.6	—1.0
1910....	— .2	—2.0	+ .8	— .2	—1.6	—1.2	—1.4	—1.8	—2.1	—2.2	— .7	—2.2
1911....	— .4	— .7	—1.6	+ .1	— .8	— .9	—1.1	— .6	—1.2	—2.2	— .3	+ .2
1912....	—1.7	— .3	—1.3	— .5	0	—1.0	— .3	— .8	— .7	+1.5	+ .2	+1.3
1913....	+ .7	—1.1	+ .4	+ .1	—1.0	— .6	0	+ .1	—1.1	— .2	+1.4	— .9
1914....	—1.4	—1.0	—1.6	0	— .6	+ .5	+ .3	+ .3	+ .7	— .3	+ .1	—2.1
1915....	— .5	— .9	—1.6	—1.6	+ .3	0	— .7	— .5	— .8	— .1	+ .7	—1.3
1916....	—1.5	—1.3	+1.5	0	— .5	—1.1	—2.0	—1.2	— .9	— .5	+1.3	+ .8
1917....	— .4	—1.2	+1.1	+ .6	0	+ .9	0	— .1	— .4	— .8	+ .6	+ .5
1918....	+ .8	+ .1	+ .1	0	+ .1	— .8	+1.3	0	+ .1	+1.6	+1.0	+1.5
1919....	+ .4	+1.6	+ .2	+1.1	— .1	+ .9	+ .4	+ .5	—1.9	—1.1	—2.2	—2.1
1920....	—2.3	—1.0	— .8	— .1	— .4	— .7	+ .4	+ .6	+ .8	+ .6	+ .2	+1.4
1921....	+3.1	+ .9	— .2	+ .5	— .8	+1.8	+ .5	— .1	— .2	— .7	— .6	+ .5
1922....	+1.5	+1.2	+ .2	+ .2	— .1	— .1	+ .3	— .1	— .6	— .6	—1.5	— .7
1923....	+2.6	— .7	+ .2	+ .3	+ .7	+ .1	+ .4	—1.0	— .1	+1.6	0	— .2
1924....	—2.5	+2.1	+ .3	+ .5	— .4	+ .3	+ .2	— .7	— .8	—1.2	—2.0	—1.3
1925....	+1.3	+ .2	— .3	— .4	+ .2	+ .3	+ .3	+1.3	+1.1	+ .9	+2.4	— .3
1926....	+1.8	+1.5	+1.1	— .4	+1.7	0	+1.0	+1.7	+1.4	+ .2	+1.0	+1.6
1927....	+2.1	+1.6	+3.0	+1.2	+2.0	+ .9	+ .9	+ .6	+ .1	+1.1	+1.5	+1.6
1928....	+1.8	— .2	+ .9	+1.4	+ .3	0	+ .8	+ .9	+6.0	+1.1	+ .9	+1.2
1929....	+1.4	+1.8	+1.5	+1.5	+1.2	+1.8	+2.4	+1.7	+1.5	+1.6	— .2	+ .5
1930....	— .5	+1.8	+1.1	— .2	+1.2	+ .4	— .2	+2.3	+2.2	+ .8	+1.6	+1.1
Means..	63.0	62.6	63.7	65.5	67.3	69.1	70.5	71.2	71.0	69.3	67.0	65.2

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MINIMUM TEMPERATURE

Station: Ewa Mill

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—5.0	—3.1	—3.0	— .7	+1.0	— .2	+ .9	+1.8	+1.3	+ .5	+1.3	—1.1
1906....	+ .1	— .5	—2.6	+1.4	— .1	+2.7	+1.5	+1.9	+1.3	+2.2	+ .8	+2.0
1907....	+3.6	+1.8	+1.4	—1.7	+ .4	+1.3	+ .6	+2.6	+2.2	+1.1	+1.7	+1.1
1908....	+ .2	+1.4	+2.3	+ .4	+1.3	— .3	— .9	— .7	—1.0	— .8	—2.0	+ .3
1909....	— .8	+ .9	+2.0	— .4	+ .7	+2.1	+1.6	— .4	— .3	+ .6	— .5	+ .7
1910....	+1.3	— .3	+1.5	+ .7	— .1	+ .8	— .6	— .7	— .5	0	+1.3	+ .9
1911....	+1.7	+1.2	+ .8	+1.9	+1.5	+1.7	+2.0	+2.1	+2.0	— .4	+ .6	+1.4
1912....	+ .5	+1.6	— .9	+1.3	+ .9	+ .4	+ .6	+ .9	+1.3	+2.5	+ .9	+3.3
1913....	+1.5	— .5	+1.1	+2.0	+ .9	+1.0	+ .4	....	+1.1	+1.6	+2.4	— .9
1914....	— .3	— .6	— .3	+ .3	+1.0	+1.5	+2.2	+2.9	+3.6	+1.6	+1.4	—1.1
1915....	— .2	+ .7	— .3	— .5	+1.3	+2.0	+1.9	+2.5	+1.8	+2.2	+2.6	+2.2
1916....	+1.7	+1.9	+2.6	+1.8	+2.0	+ .9	+ .1	—1.3	— .2	+ .9	+2.0	+ .6
1917....	— .5	— .2	+1.8	+ .4	— .3	0	— .7	— .6	— .6	— .6	+ .7	+ .4
1918....	+ .6	+1.5	— .3	+ .5	— .9	+ .1	+1.6	+ .6	— .4	+1.7	— .4	+ .9
1919....	—1.7	+ .9	— .8	0	— .2	+ .1	+ .5	+ .6	—1.2	— .4	—1.1	—1.8
1920....	—1.2	— .8	+ .1	— .6	—1.2	—2.0	+ .5	0	+ .1	+ .1	—1.1	+ .1
1921....	+2.2	— .5	— .5	— .2	—1.9	+ .9	— .6	—1.1	— .6	—2.0	—1.3	+ .2
1922....	+ .2	+ .5	— .4	— .1	—1.6	—2.4	—2.4	—2.3	—1.9	—1.8	—2.1	—3.5
1923....	+1.6	—3.6	—1.2	—1.1	—1.4	—2.6	—1.3	—2.1	—1.6	—2.1	—1.7	—1.3
1924....	—5.7	—1.7	—2.9	—2.6	—2.2	—3.8	—2.8	—3.6	—3.7	—2.2	—3.0	—3.3
1925....	+1.2	—1.1	—2.1	—1.6	—2.5	—2.6	—3.0	—3.1	—4.1	—3.9	—2.1	— .5
1926....	+ .1	+ .8	— .3	—2.3	+1.6	+ .6	+ .1	— .4	+ .5	+ .4	— .9	+1.4
1927....	+1.3	+ .5	+2.7	+ .8	+1.3	+ .8	—1.9	— .7	— .6	— .7	+1.4	+ .6
1928....	+ .8	+1.7	— .6	+ .3	— .2	—1.3	— .3	— .6	—1.3	— .9	— .5	+ .1
1929....	—1.7	+ .4	+ .5	+ .6	— .5	— .2	—1.4	— .6	+ .2	+1.0	+ .5	—1.0
1930....	—1.6	0	+ .4	—1.2	— .1	— .3	+ .6	+1.6	+1.4	— .2	— .8	....
Means..	60.9	60.4	61.6	63.3	64.7	66.5	67.9	68.6	67.9	66.5	64.5	62.8

Station: Kahuku

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—1.5	—2.5	— .6	— .1	+ .1	+ .1	+ .3	— .6	— .4	— .5	+ .4	+ .6
1906....	+ .6	— .4	—2.6	+1.2	— .5	+1.3	+1.2	+ .3	— .2	+1.1	+ .5	— .4
1907....	+1.2	+2.2	— .3	—2.0	+ .1	— .2	— .5	—1.1	— .1	— .1	— .7	— .1
1908....	— .2	0	— .4	—1.1	— .3	—1.5	—2.2	—2.2	—1.9	—1.7	—2.7	— .9
1909....	—1.9	—1.5	—2.7	—3.6	—1.8	—2.8	—3.2	—3.1	—3.0	—3.1	—3.5	—3.7
1910....	—1.1	— .7	+1.7	+ .8	—1.0	— .5	+ .2	— .2	+ .1	— .8	+1.2	—1.8
1911....	+ .6	— .2	— .4	+ .8	+ .6	+ .1	+ .7	+ .4	+ .3	—1.7	+ .4	+ .5
1912....	—1.0	— .3	+ .5	+ .5	+ .6	— .6	+ .2	+ .2	— .1	+2.7	+1.0	+3.1
1913....	+ .3	0	+1.2	+1.2	+ .5	+ .5	+1.4	+1.4	+1.5	— .5	+2.1	—1.7
1914....	—1.2	— .4	— .9	—1.1	— .4	+ .8	+1.1	+1.4	+1.0	+1.5	+2.8	+5.1
1915....	+6.2	....	....	+3.3	—1.6	+1.3	+ .9	+2.2	+1.6	+2.5	+2.2	+2.7
1916....	+2.9	+5.3	+2.3	+4.6	+1.3	+ .1	— .9	— .6	+ .3	+ .2	+1.4	+ .3
1917....	— .9	—2.2	+1.1	+ .6	+ .3	+1.2	+ .6	+ .6	— .6	—1.5	+ .4	— .9
1918....	+ .6	+ .9	+1.0	— .3	— .7	— .5	+1.6	+ .7	+ .2	+1.9	+ .3	+1.6
1919....	+ .7	+1.5	0	+ .5	+ .6	+1.7	+1.0	+ .1	—1.8	+ .7	—1.2	—3.5
1920....	—1.5	+ .5	—1.3	— .4	— .9	+ .9	—3.6	+ .3	+1.3	+2.1	....	+4.3
1921....	—3.1	—2.2	+ .8	+1.6	+ .7	+2.4	+1.8	+2.0	+1.2	—1.2	+1.5	+ .6
1922....	+ .7	+1.6	0	+ .8	+1.2	+ .7	+ .3	0	0	— .4	—1.2	+1.5
1923....	+1.0	—1.9	—1.8	— .8	— .7	— .9	— .5	— .2	+ .6	— .3	— .2	—1.1
1924....	—2.6	— .2	— .5	—2.4	—1.3	—1.6	—1.6	—2.1	— .4	—1.6	—2.7	—2.3
1925....	+1.0	— .4	—1.1	—1.5	—1.0	—1.4	—1.6	— .9	—1.1	—1.6	— .1	—3.7
1926....	—1.6	— .4	+ .2	—3.2	— .5	—2.5	— .1	—1.0	+ .5	—1.3	—1.1	—2.4
1927....	+ .1	—2.2	— .3	—2.0	— .6	—2.2	—1.4	—1.5	—1.4	— .1	+1.8	+ .8
1928....	+2.8	+ .1	+1.4	+1.8	+1.9	+1.0	+1.4	+ .5	+1.0	+1.1	+ .2	+2.2
1929....	+ .4	+2.6	+2.9	+2.3	+1.2	+1.5	+2.9	+1.4	+1.1	+1.4	—1.7	— .8
1930....	—2.6	+1.1	+ .2	— .5	+1.4	+ .7	+ .9	+1.7	+1.3	+ .5	— .7	+ .9
Means..	63.9	63.4	64.8	66.8	68.3	70.2	71.0	71.9	71.6	70.2	68.1	66.2

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MINIMUM TEMPERATURE

Station: Waialua Mill

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—1.8	— .6	+2.7	+ .2	+2.1	+ .7	+1.0	+1.8	+1.7	+ .5	+ .4	— .5
1906....	+ .3	— .2	— .8	+ .4	+ .4	+1.7	+ .3	+ .5	+ .6	— .3	— .8	+ .7
1907....	+2.4	+1.1	+ .7	—3.8	+ .5	+ .8	+1.1	+2.1	+3.1	+1.2	— .4	—2.3
1908....	—4.5	—2.5	—3.2	—3.8	—4.2	—2.7	— .3	— .7	—1.0	— .9	—3.3	— .4
1909....	— .5	+1.0	+ .1	—1.2	—1.8	—1.0	—2.5	—2.5	—1.7	— .3	— .7	+1.4
1910....	+ .4	— .6	+1.0	+ .3	— .5	+ .7	— .1	+ .9	+1.3	+ .5	+ .3	— .9
1911....	+2.2	+ .9	+1.4	+1.6	+ .6	— .1	+ .5	+1.6	+1.3	— .7	+ .8	+ .4
1912....	— .2	+ .4	—1.0	— .3	+ .3	+ .3	+ .7	+1.0	+ .5	+2.0	+ .7	+2.3
1913....	+ .8	+ .2	+1.0	+1.1	+ .2	+ .9	+ .6	+2.1	+1.4	+1.9	+2.8	—1.0
1914....	0	— .6	— .1	+ .7	+1.4	+1.6	+3.4	+4.0	+3.3	+1.2	+ .6	+ .7
1915....	+2.5	+1.8	+1.0	+ .8	+1.9	+1.2	+1.3	+2.2	+2.0	+1.9	+3.1	+3.3
1916....	+2.4	+2.1	+2.4	+1.8	—1.5	+1.1	+1.0	—1.2	— .5	+1.2	+ .7	— .5
1917....	— .6	+ .2	+1.2	+2.6	— .3	— .5	—1.6	—1.4	— .7	— .1	— .3	+1.4
1918....	+ .1	+1.0	+ .6	+1.0	+ .5	+ .4	+3.2	+2.0	+1.6	+2.1	+2.7	+2.6
1919....	+1.3	+3.7	+ .7	+ .9	+ .9	+1.4	+1.5	+2.1	+ .3	+ .4	+ .1	+ .6
1920....	+1.0	+1.1	+ .2	+ .3	+1.2	+ .9	+ .6	+1.2	+ .2	+ .6	— .2	+1.5
1921....	+3.7	+1.1	+ .7	+ .3	+ .8	+2.5	+1.6	+ .7	+ .8	— .6	+1.3	+ .6
1922....	+1.0	+1.1	+ .7	+ .1	— .7	— .5	— .5	— .5	+ .3	+ .5	+ .7	—1.3
1923....	+1.7	+ .1	+ .8	+ .4	— .1	—1.4	—1.1	—1.9	—1.4	—1.6	—1.9	—1.5
1924....	—5.0	—2.5	—3.5	0	+3.9	+1.9	— .2	—2.4	— .2	— .3	—1.3	—3.1
1925....	—2.8	—2.8	—2.6	— .4	— .1	+ .2	— .3	+1.2	— .9	+ .1	+ .4	+ .4
1926....	—1.2	— .9	—4.0	—6.4	—2.6	—2.9	—1.2	—2.0	—2.7	—2.1	— .7	+ .5
1927....	0	+ .7	+ .2	— .2	+ .6	—2.0	—3.3	—3.4	—2.9	—2.5	+ .7	— .3
1928....	— .7	—4.5	—3.1	—1.5	—3.5	—4.3	—3.2	—2.8	—3.5	—4.7	—3.7	—3.0
1929....	—2.8	— .1	+ .7	+ .1	0	+ .8	—1.0	—2.8	—1.8	—1.5	—3.6	—2.5
1930....	—1.0	0	+1.7	—2.1	+1.1	— .5	—2.1	—2.3	— .4	+ .7	+1.6	+1.8
Means..	60.7	60.0	60.8	62.6	63.9	65.4	66.6	67.0	66.4	65.4	63.9	62.1

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MINIMUM TEMPERATURE

Station: Waianae

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	....	—2.5	—1.2	+1.4	+1.5	+ .8	+ .2	+2.8	+1.8	+ .2	+ .1	— .4
1906....	+1.6	0	—2.4	— .7	+1.2	+4.2	+1.5	+ .9	+1.0	+1.7	— .1	+1.2
1907....	+1.4	0	+ .7	—3.0	—2.9	—4.9	—4.9	+2.6	+2.2	+1.8	+1.7	+ .8
1908....	+ .9	+ .9	+ .7	+ .1	+ .9	+ .7	—1.7	—1.0	— .9	—1.6	—2.3	+1.9
1909....	+1.5	+ .1	+ .4	—1.3	....	....	+1.5	— .1	— .6	— .4	— .9	— .5
1910....	+ .6	—1.4	+ .8	—1.0	—6.2	—6.6	....	— .6	—1.2	— .6	—1.2	— .8
1911....	+ .9	— .3	— .5	— .9	—1.3	+ .8	+1.4	+ .9	+1.2	—2.9	— .4	—1.1
1912....	— .3	+1.2	—2.2	— .7	— .2	—1.2	— .8	— .8	—1.0	+1.4	—1.2	— .2
1913....	—1.2	+ .1	+ .9	+ .2	—3.1	—2.3	—1.7	+ .1	— .8	—1.2	0	—3.0
1914....	—1.3	— .3	—3.2	—1.6	—2.0	0	+1.1	+1.6	+1.4	—1.0	—1.9	— .7
1915....	—3.4	— .4	—1.8	—3.3	+ .7	+1.6	+1.2	+ .6	— .2	+2.6	+1.5	+1.3
1916....	— .7	+ .8	+ .5	+ .8	+1.5	+ .8	+ .6	—1.5	— .6	—1.0	0	+ .4
1917....	— .9	—1.5	— .7	—2.4	—2.7	—1.0	—2.3	—2.9	—2.2	—2.8	—1.7	—2.3
1918....	—1.9	—1.1	—3.2	—1.7	—1.6	+ .1	+ .5	— .2	—1.3	—1.0	— .5	—2.1
1919....	—1.5	+ .8	—1.0	— .8	—1.6	—1.1	— .3	+ .3	—2.3	—1.1	—2.6	—1.6
1920....	— .8	— .9	—2.8	+1.9	—1.1	—4.1	—6.1	—3.5	—3.1	+ .3	—1.3	+ .7
1921....	+4.3	+ .4	—1.1	+1.1	— .2	—2.7	—3.3	— .2	+1.0	— .6	+ .9	+2.3
1922....	+1.8	+2.2	— .2	+ .5	+ .5	+ .3	0	+ .5	+ .7	— .6	— .4	—1.7
1923....	+3.3	— .9	+ .9	— .1	+2.3	+ .5	+2.3	—1.9	— .2	+ .2	+1.0	+1.3
1924....	—2.5	—1.7	— .3	+ .4	+1.1	+2.8	+ .6	—2.2	— .8	+1.1	+ .9	+3.1
1925....	+3.5	+2.9	+5.6	+4.0	+1.7	+1.1	+ .1	—1.3	—1.3	+ .5	+1.7	—3.3
1926....	—1.3	+1.9	+2.0	— .8	+3.6	+1.0	— .4	—2.4	+ .3	0	— .2	+4.3
1927....	+2.6	—2.9	0	+2.7	+3.2	+2.8	+3.2	+2.7	+1.7	+2.3	+4.2	—4.5
1928....	—4.0	—1.7	+2.2	+2.9	+1.7	+1.2	+3.8	+2.0	+2.7	+2.3	+2.1	+3.7
1929....	0	+ .8	+2.3	+2.0	+1.5	+2.8	+2.8	+1.5	+1.1	+1.9	— .6	— .3
1930....	—1.8	+4.7	+3.9	+4.0	+3.0	+2.3	+1.4	+2.9	+2.5	—1.6	+ .1	+1.4
Means..	62.4	62.0	63.6	65.3	66.7	68.0	69.8	70.9	70.0	68.6	66.4	64.2

TABLE E

DEPARTURES FROM AVERAGE OF MEAN MINIMUM TEMPERATURE

Station: Waimanalo

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—4.2	—2.7	....	—4.3	— .2	— .8	— .3	0	— .5	— .6	+ .2	+ .6
1906....	+ .1	—1.2	—4.2	— .1	—7.4	+1.5	+ .5	+ .5	— .1	+1.2	+1.2	+ .9
1907....	+2.3	+1.8	— .2	—1.7	0	+1.6	+1.1	+ .9	+1.5	+1.1	— .1	+2.1
1908....	+ .9	+2.2	+1.1	+1.4	+2.0	0	— .4	— .5	— .1	— .2	—1.0	+1.2
1909....	+ .7	+ .4	+ .1	—1.1	+1.1	+ .3	— .4	— .2	— .3	— .8	—1.1	+ .2
1910....	+1.5	—1.2	+ .8	+1.4	—1.3	— .7	— .6	— .6	— .8	— .7	+1.0	—1.7
1911....	+1.9	+ .3	— .6	+1.5	+ .4	+ .1	+ .2	+ .9	— .1	—1.3	+1.0	+1.3
1912....	+ .5	+ .6	— .2	+1.3	+ .7	0	+ .3	+ .3	— .1	+2.2	+1.0	+3.5
1913....	—1.1	0	+ .2	+2.1	+ .6	+ .4	+ .4	+1.0	— .2	+ .6	+2.4	—2.1
1914....	—1.2	— .8	—1.8	— .3	— .2	+ .6	+ .3	— .7	+ .7	0	— .2	+ .9
1915....	+2.4	+ .3	— .5	— .7	+1.3	+ .8	+ .7	+ .5	+ .5	+1.3	+1.3	+1.6
1916....	+ .6	+1.4	+2.4	+1.8	+ .6	+ .8	+ .4	— .9	+ .1	+ .9	+1.7	+1.3
1917....	— .6	—1.8	+1.2	+1.4	+ .5	+ .9	— .3	+ .4	— .4	— .5	— .4	+ .5
1918....	+1.5	+ .9	— .3	— .2	— .2	— .1	+1.3	+ .6	+1.1	+2.2	+1.2	+1.7
1919....	+1.0	+2.6	+ .3	+1.1	+ .3	+ .3	+ .2	+ .2	— .5	+ .9	+ .3	— .2
1920....	—1.0	+1.5	— .6	—1.0	— .5	+ .8	+ .7	+ .7	+ .3	+ .4	—4.1	—7.0
1921....	—4.9	— .4	— .7	+ .9	— .2	+1.0	+ .2	0	+1.2	— .1	— .2	— .1
1922....	+ .2	+1.2	+ .7	+ .8	+1.4	— .3	+ .7	0	— .4	— .5	— .6	— .5
1923....	+1.7	—2.1	—1.2	+1.4	+ .5	— .9	— .4	— .1	+ .8	— .6	—1.1	—3.0
1924....	— .9	+ .2	—2.0	—2.0	— .1	— .9	— .8	—2.0	—2.0	— .8	— .9	— .7
1925....	+ .9	—1.6	+ .8	— .2	— .3	— .7	— .6	— .3	+ .9	—1.9	— .6	+ .7
1926....	....	—3.8	0	—6.6	0	—2.0	— .4	— .5	—1.1	—1.5	— .3	— .9
1927....	—2.8	—3.4	+ .2	—2.0	+ .4	—1.2	—1.1	— .6	— .6	— .5	— .5	—1.3
1928....	+1.0	+1.2	+1.5	+2.1	— .6	— .6	—2.3	—1.1	—1.3	— .5	—2.4	— .9
1929....	— .3	+3.5	+1.7	+2.4	+ .6	+ .1	+ .3	— .1	0	— .4	— .5	—1.1
1930....	+ .8	+1.3	+ .6	0	+ .9	+ .2	+ .1	+1.4	+1.2	+ .7	— .4	+1.8
Means..	64.4	64.6	66.0	67.4	69.2	71.3	72.5	73.0	72.8	71.1	69.1	66.8

TABLE E

DEPARTURES OF MEAN MINIMUM TEMPERATURE FROM AVERAGE

Station: Waipahu

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1906....	+ .1	— .3	—2.5	+ .7	+1.5	+2.8	+5.7	+1.6	+1.5	+2.1	—1.9	+2.0
1907....	+3.2	+2.5	+1.0	—1.9	— .2	+ .5	+ .1	+2.9	+1.2	+ .5	— .1	+ .5
1908....	— .7	+ .8	+1.4	— .3	+ .8	— .5	—1.2	— .6	0	— .6	—1.8	+ .2
1909....	— .9	+ .2	+ .4	—1.5	— .5	+ .3	— .6	—2.1	—1.4	— .5	—1.4	— .5
1910....	+ .1	—1.6	— .5	— .6	—1.4	—1.2	—2.2	—2.2	—1.4	—1.5	— .1	—2.4
1911....	0	— .3	—1.2	— .5	—1.1	—1.0	—1.0	— .5	+ .4	—2.4	— .8	— .4
1912....	—1.2	— .1	—2.4	— .3	— .7	—1.4	— .9	— .5	— .6	+ .4	— .9	+1.3
1913....	— .3	—2.0	— .8	+ .2	—1.4	— .6	— .9	— .3	— .8	— .4	+1.9	—2.3
1914....	—2.1	—1.6	—1.9	—1.1	—1.3	+ .1	+1.6	+2.0	+1.8	0	—1.1	—3.2
1915....	—2.0	— .6	—2.4	—1.1	+ .7	— .1	— .1	+ .4	+ .1	—2.0	+ .8	— .1
1916....	+ .8	+ .4	+ .6	— .3	+ .3	— .8	—1.5	—2.6	—1.3	— .7	— .1	— .6
1917....	—1.6	—1.8	0	— .9	—1.7	+ .9	—2.4	—2.2	—1.7	—2.3	— .8	—1.0
1918....	— .5	— .1	—1.1	— .7	—2.1	—1.1	+ .1	— .6	—1.3	+ .5	— .3	0
1919....	—2.3	+ .5	—1.5	— .7	— .9	—1.4	— .5	....	—1.8	—1.5	—1.7	—2.0
1920....	—2.0	—1.2	— .4	—1.3	—1.8	—1.0	— .8	— .7	— .9	— .4	—1.2	— .2
1921....	+1.8	0	— .8	+ .5	—1.6	+1.1	+ .2	—1.6	— .8	—1.9	— .8	0
1922....	— .4	+ .8	— .9	— .5	—3.0	—2.0	—1.1	+ .5	—1.1	+ .6	+1.1	—2.1
1923....	+1.6	—2.5	— .9	— .3	— .3	—1.0	—1.8	—2.3	— .7	— .7	—1.3	....
1924....	....	....	+3.7	+4.4	+3.8	+1.4	+1.9	+2.0	+3.2	+2.8	+3.1	+3.2
1925....	+3.5	+3.3	+3.8	+3.1	+2.8	+3.2	+3.3	+3.3	+1.1	+2.0	+2.8	+2.9
1926....	+2.4	+2.5	+2.2	— .1	+3.1	— .8	—1.2	— .2	+ .9	+1.8	+ .8	+3.0
1927....	+3.5	+1.6	+4.0	+2.3	+4.0	+2.9	+2.5	+2.1	+2.0	+2.2	+3.2	+ .9
1928....	+1.4	—1.6	+ .6	+ .9	+ .2	— .7	+ .5	— .1	— .6	— .1	+ .3	+ .2
1929....	—1.8	— .2	+ .3	+ .8	+ .7	+ .6	+ .2	+ .3	— .2	+ .7	—1.3	— .8
1930....	—2.5	+ .5	— .3	—1.2	+ .2	+ .2	— .1	+1.7	+1.4	+ .7	+ .9	+1.4
Means..	62.3	61.7	63.0	64.5	65.8	67.7	69.0	69.6	68.9	67.7	66.0	64.1

TABLE F

MEAN DAILY RANGE OF TEMPERATURE

Station	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
OAHU													
Ewa	17.7	19.2	18.3	18.3	19.0	18.8	18.3	18.2	18.7	18.7	18.0	17.4	18.4
Kahuku	13.9	15.3	13.3	12.1	12.4	12.3	12.7	12.1	13.0	13.6	13.1	13.4	12.9
Waialua	17.0	18.5	18.5	18.5	19.9	20.5	20.5	20.2	20.0	18.8	17.1	16.7	18.9
Waianae	18.3	19.2	18.4	18.2	18.8	19.1	19.0	19.2	18.7	18.8	18.7	18.8	18.8
Waimanalo	13.2	14.0	12.9	12.2	12.7	14.3	12.4	12.4	12.6	13.2	12.2	11.8	12.8
Waipahu	15.8	17.6	16.9	16.4	17.4	16.8	16.4	16.4	17.1	16.9	16.1	15.6	16.6
KAUAI													
Eleele	15.8	16.7	16.4	15.4	14.8	14.1	13.1	14.4	14.2	14.9	14.3	14.9	14.9
Kealia	15.7	16.7	15.0	13.9	13.7	12.9	12.9	13.0	13.8	14.1	14.2	14.6	14.2
Kilauea	14.7	15.9	14.3	13.4	14.2	13.5	13.4	13.0	13.8	13.7	13.2	13.5	13.9
Koloa	15.1	15.9	14.5	13.9	13.4	13.0	13.4	13.7	14.4	14.7	13.8	13.6	14.1
Lihue	16.3	17.2	15.5	14.3	14.3	13.8	13.8	13.8	14.4	15.1	14.8	15.0	14.9
Makaweli	16.4	17.4	16.9	17.0	17.0	16.7	16.8	17.2	17.0	17.0	16.3	16.4	16.8
MAUI													
Hana	13.3	13.9	12.9	11.9	12.6	12.1	11.9	12.2	14.5	13.0	12.7	12.8	12.8
Kaanapali	17.7	19.2	18.3	17.9	19.0	19.0	19.8	20.2	20.1	20.1	18.8	17.9	19.0
Puunene	15.4	18.2	16.5	15.5	16.5	16.2	15.9	15.4	16.1	16.7	16.0	15.1	16.1
Wailuku	14.6	15.7	14.8	14.0	14.3	14.0	13.4	13.8	14.0	14.6	14.3	13.7	14.3
HAWAII													
Hakalau	13.1	13.9	13.0	12.8	12.9	13.1	12.7	12.7	13.4	13.2	13.1	13.1	13.1
Hilo	14.8	15.5	14.5	13.9	14.8	14.5	14.4	14.1	14.8	14.8	14.4	14.6	14.5
Honokaa	16.2	17.1	16.4	15.9	15.9	16.5	15.8	15.4	16.4	16.5	16.1	15.4	16.1
Kohala	15.0	15.0	14.4	13.8	14.5	13.6	13.1	13.0	13.2	14.4	14.1	13.7	14.0
Olaa	19.6	21.2	20.0	18.2	18.5	18.4	17.9	17.5	18.1	18.6	18.3	16.7	18.6
Ookala	14.6	15.1	14.8	14.1	14.7	15.4	15.2	14.9	14.2	15.0	14.5	14.2	14.7
Pahala	19.4	20.1	19.4	19.3	19.4	19.8	20.6	20.5	20.2	19.8	19.4	19.0	19.7
Pepeekeo	14.3	14.9	14.1	12.6	13.6	13.7	13.5	13.5	13.4	14.6	14.3	14.2	14.0

TABLE G-I

EXTREMES OF MEAN MAXIMUM TEMPERATURE

Station	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
OAHU												
Ewa	81.5	84.0	82.1	83.7	85.2	87.0	87.6	88.5	87.9	87.2	84.0	82.3
	73.5	75.4	75.7	77.7	79.8	81.5	82.4	82.4	81.9	80.1	79.0	75.6
Kahuku	80.2	82.8	80.9	82.4	83.9	86.0	87.5	87.2	87.3	87.6	84.6	86.0
	74.2	75.8	74.3	76.6	77.8	79.8	81.0	81.3	81.3	80.4	78.7	77.2
Waialua	81.4	81.0	83.5	84.3	86.9	90.2	92.2	91.9	89.3	87.9	82.9	81.7
	74.8	74.6	76.9	78.4	81.4	82.8	83.9	82.0	81.8	80.2	78.2	76.3
Waianae	87.4	85.6	86.1	86.6	87.3	89.5	91.1	91.6	90.5	90.4	89.5	89.1
	78.0	78.8	78.8	79.4	84.2	83.3	86.7	87.9	84.2	81.5	82.4	79.2
Waimanalo	80.6	83.0	82.1	82.4	88.0	87.3	87.3	88.9	88.6	87.6	84.2	86.2
	75.1	74.8	76.4	76.0	76.0	78.4	81.5	82.0	81.4	80.1	77.3	73.8
Waipahu	82.1	84.3	86.0	84.3	85.7	86.8	87.3	87.7	87.7	88.1	85.0	84.4
	74.4	76.9	77.2	77.0	81.4	82.0	81.2	81.0	81.5	80.7	79.4	76.0
MAUI												
Hana	82.1	83.2	84.0	82.8	85.3	85.0	84.3	84.0	86.2	85.3	82.9	82.3
	73.6	72.4	72.5	75.2	77.3	77.8	80.2	80.7	78.9	78.2	76.8	73.3
Kaanapali	87.1	85.4	84.8	86.3	89.1	89.3	91.2	92.9	93.0	92.3	92.9	87.5
	73.7	75.3	76.6	75.6	83.2	84.6	86.0	86.0	80.3	80.0	77.7	74.5
Wailuku	80.7	82.0	82.3	82.4	85.3	85.9	87.0	87.7	88.4	86.7	84.6	83.5
	70.8	71.8	69.7	75.1	76.7	75.4	76.8	77.6	81.9	80.6	75.3	72.5
KAUAI												
Eleele	82.6	84.4	84.7	82.1	83.9	85.5	86.2	89.1	87.9	86.3	85.8	83.9
	72.8	75.6	75.8	76.4	78.6	80.0	78.9	80.9	80.5	80.5	78.8	75.6
Kealia	81.0	81.4	83.4	82.8	85.2	85.9	88.2	88.7	90.0	87.7	85.0	82.8
	73.8	75.2	70.7	76.6	77.9	79.6	80.2	80.7	80.8	79.7	79.0	76.4
Kilauea	82.6	81.3	82.8	81.6	83.2	84.9	85.4	86.2	86.2	85.2	82.3	81.8
	72.5	74.6	74.1	72.7	77.1	78.7	80.5	81.1	80.6	79.0	74.4	73.0
Koloa	80.0	79.6	79.6	79.9	80.9	83.5	83.8	84.8	85.1	84.7	82.1	80.0
	73.6	74.4	73.5	73.9	77.6	79.1	79.1	80.5	81.1	80.5	76.0	74,1
Lihue	79.0	80.6	80.0	80.1	83.0	84.0	85.5	86.3	86.2	82.6	81.2	85.1
	74.2	74.1	74.4	74.7	77.4	79.0	81.4	81.8	80.4	74.0	74.6	81.3
Makaweli	82.0	82.6	82.4	84.6	85.6	88.9	88.4	88.8	88.6	87.0	85.4	85.4
	71.4	74.5	75.5	78.6	81.6	82.8	83.1	85.4	84.1	82.3	75.8	74.0
HAWAII												
Hakalau	81.3	80.1	78.7	81.0	84.1	84.5	84.1	83.5	84.4	83.7	82.6	81.6
	68.6	72.5	73.2	74.4	76.3	71.5	78.4	79.2	78.7	78.5	75.4	71.9
Hilo	80.7	81.8	80.0	82.0	84.7	85.1	84.8	84.5	86.3	84.6	82.4	83.2
	74.8	72.8	73.3	74.9	77.5	77.4	77.6	80.1	79.2	77.2	74.5	75.1
Honokaa	82.0	82.2	82.6	84.9	76.4	85.9	86.3	86.7	85.9	86.0	83.6	84.2
	73.4	75.4	73.1	73.9	77.0	78.5	79.4	79.2	79.3	79.0	77.4	74.7
Kohala	80.0	80.6	80.7	81.1	83.1	85.6	85.6	86.6	84.3	86.4	82.5	82.3
	73.9	72.8	74.0	75.2	77.0	77.5	78.6	78.9	78.3	79.1	77.2	73.5
Olaa	86.3	87.7	86.7	83.9	85.5	89.0	87.5	89.7	90.0	89.0	87.0	89.2
	75.4	75.9	76.8	73.4	74.4	75.6	76.1	78.8	78.9	77.0	74.1	72.7
Ookala	82.3	81.2	81.8	82.9	84.0	84.8	85.1	85.4	86.5	85.5	83.0	85.4
	73.6	72.5	74.0	75.0	76.6	77.4	78.6	79.2	78.1	78.4	77.3	74.8
Pahala	80.8	82.3	81.8	82.4	84.1	85.2	87.5	87.3	87.8	86.9	85.9	83.6
	73.5	75.0	77.0	77.8	78.0	78.6	80.6	80.9	79.6	81.0	78.5	76.8
Pepeekeo	81.8	82.4	81.9	80.6	83.0	82.9	83.6	85.0	86.2	85.0	84.2	83.1
	72.6	71.6	70.9	72.4	74.3	75.1	76.2	77.3	78.4	77.5	76.0	74.3

TABLE G-II

EXTREMES OF MEAN MINIMUM TEMPERATURE BY MONTHS

Station	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
OAHU												
Ewa	64.5	62.3	64.3	65.3	66.7	69.2	70.1	71.5	71.5	69.0	67.1	66.1
	55.2	57.3	58.6	60.7	62.2	62.7	64.9	65.0	63.8	62.6	61.5	59.5
Kahuku	70.1	68.7	67.7	71.4	70.2	72.6	73.9	74.1	73.2	72.9	70.9	71.3
	60.8	60.9	62.1	63.2	66.5	67.4	67.4	68.8	68.6	67.7	64.6	62.5
Waialua	64.4	63.7	63.5	70.4	67.8	67.9	70.0	71.0	69.7	67.5	67.0	65.4
	55.7	55.5	56.8	56.2	59.7	61.1	63.4	63.6	63.5	60.7	60.2	59.0
Waianae	66.7	66.7	69.2	69.3	70.3	72.2	73.6	73.8	72.7	71.2	70.6	68.5
	58.4	59.1	60.4	62.0	60.5	61.4	63.7	67.4	66.9	65.7	63.8	59.7
Waimanalo	66.8	68.1	68.4	69.8	70.6	72.9	73.8	74.4	74.3	73.3	71.5	68.9
	59.5	60.8	61.8	60.8	61.8	69.3	70.2	71.0	70.8	69.2	65.0	59.8
Waipahu	65.8	65.0	67.0	68.9	69.8	70.9	72.3	72.9	72.1	70.5	69.2	67.3
	59.8	59.2	60.5	62.6	62.8	65.7	66.6	67.0	67.1	65.3	64.1	61.7
KAUAI												
Eleele	66.3	66.6	67.2	67.4	77.7	72.3	74.6	74.6	74.2	71.1	70.8	68.6
	59.2	58.8	59.8	62.1	63.4	65.5	67.4	67.3	67.0	65.9	63.7	61.7
Kealia	67.0	65.0	67.1	69.1	70.8	71.9	73.7	75.4	73.6	72.7	69.7	68.6
	56.3	59.0	57.6	60.2	62.1	63.6	64.1	63.2	64.2	63.5	62 8	59.2
Kilauea	64.5	63.9	64.8	65.9	67.2	69.3	70.6	72.6	70.5	69.9	67.8	65.8
	58.2	58.4	59.5	61.6	64.3	65.2	67.0	67.8	67.7	66 5	63.4	60.0
Koloa	65.3	64.0	65.5	67.0	68.2	70.6	71.7	72.9	72.3	70.5	68.8	67.0
	57.0	58.5	57.0	56.7	61.3	67.3	69.4	68.9	68.8	66.8	63.8	60.6
Lihue	64.4	62.8	64.9	66.8	68.5	70.0	71.1	72.8	71.1	69.9	67.9	66.2
	55.6	57.1	57.2	60.2	63.3	65.6	63.3	64.6	66.9	65.8	61.3	59.1
Makaweli	65.0	64.6	65.8	66.0	67.8	70.7	71.1	72.1	71.2	70.8	69.0	68.2
	57.6	59.9	60.5	61.4	64.3	66.9	67.2	66.5	64.8	64.0	63.2	60.6
MAUI												
Hana	67.8	68.9	68.8	69.8	72.1	72.8	74.0	74.2	71.3	72.4	71.3	69.4
	58.8	59.3	57.3	62.2	61.5	65.3	65.5	65.1	64.0	64.8	63.0	62.5
Kaanapali	66.4	63.4	64.7	68.1	72.0	72.9	70.9	71.7	70.9	70.5	68.6	68.3
	54.5	55.1	56.7	57.7	59.0	62.4	61.6	62.7	62.4	62.0	59.5	56.7
Wailuku	66.1	64.7	66.7	67.0	69.3	70.9	72.9	73.5	77.0	70.9	69.4	66.8
	58.1	60.0	59.2	62.8	65.7	67.9	68.5	69.1	68.9	67.1	65.4	63.0
HAWAII												
Hakalau	67.6	66.1	67.0	67.5	77.9	69.1	71.5	72.1	71.4	71.4	70.2	68.5
	56.2	55.6	54.5	58.5	63.0	64.2	64.8	64.5	63.3	61.3	58.4	58.3
Hilo	64.3	64.6	65.7	65.9	67.7	68.6	70.8	70.8	70.0	68.6	68.0	65.4
	59.7	59.6	60.7	61.6	62.7	63.7	64.5	64.4	63.9	63.7	62.4	62.2
Honokaa	63.9	63.8	64.9	65.6	67.5	69.0	70.7	70.5	69.4	69.5	66.8	65.4
	57.6	57.5	58.3	59.2	61.0	63.0	63.9	64.1	63.9	63.1	61.7	60.7
Kohala	64.8	66.9	66.6	65.8	68.8	69.6	70.7	72.5	72.6	69.4	69.1	66.4
	55.9	60.6	60.1	58.6	58.8	63.5	61.8	62.5	66.0	60.0	64.1	63.0
Olaa	63.2	62.2	63.6	64.3	65.7	66.0	67.5	69.1	68.7	66.5	65.4	64.0
	53.9	49.7	55.2	54.2	51.6	53.4	57.5	60.3	62.0	60.0	59.6	58.3
Ookala	67.4	66.0	68.8	66.8	70.3	74.4	69.4	69.5	73.2	71.4	70.7	67.2
	59.3	60.3	60.0	61.9	61.8	58.5	61.0	61.8	66.2	64.3	64.5	62.1
Pahala	62.0	61.0	62.5	63.4	63.7	64.9	65.5	67.7	67.5	65.7	65.1	63.3
	56.0	55.5	54.9	57.1	58.5	58 9	59.5	57.9	57.2	57.9	59.1	58.1
Pepeekeo	66.1	65.3	65.4	66.3	67.7	68.4	69.8	70.3	70.6	68.9	68.6	66.4
	61.6	59.6	61.5	63.1	64.1	63.1	62.7	62.6	64.4	63.8	63.8	62.7

Rainfall Data

Rainfall data are available for 31 stations. We have omitted detailed presentation of the rainfall data on irrigated plantations as such data would be of little practical interest.

Normal Monthly Rainfall

Table H gives the normal monthly rainfall of the plantations.

One characteristic feature of our monthly rainfall is that more rain falls in winter than in summer, whereas from the point of view of cane production we should have generally more rain in summer than in any other season.

Monthly Rainfall Data

Table I gives the rainfall by months of the unirrigated plantations from 1905-1930.

The importance of rainfall to sugar production is fully recognized. It is not the total annual rainfall that is of importance, but its distribution over the seasons. Ideal conditions would be—ample rain in summer when the cane is growing rapidly, and comparatively little rain in winter when the growth is slow or when the cane needs to be ripened. High yields in unirrigated plantations are associated with more or less ideal conditions. Fig. 8 shows the distribution of rainfall for some high-yield years and some poor-yield years at the Pepeekeo Sugar Company.

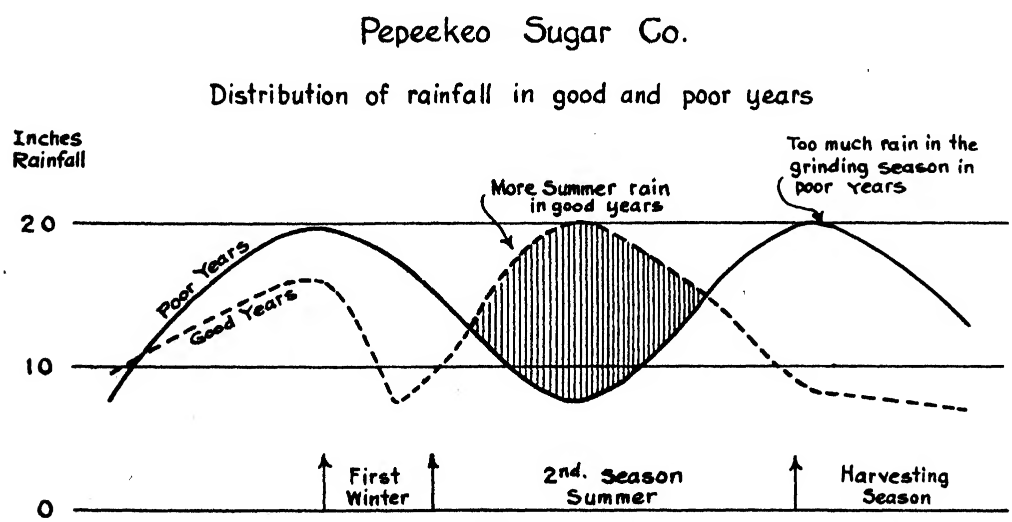


Fig. 8

A month-to-month progress of rainfall can be kept on a wall chart similar to that shown for temperature in Fig. 5. This will help the plantation to follow the progress of the crop intelligently. Probably data on seasonal rainfall will be just as useful because the deficiency of rainfall in one month of a season may be made up by an excess in another month of the same season.

The detailed table should be of help in studying the sequence of rainfall. Does one wet month follow another? Is there any periodic fluctuation, etc.?

Monthly Rainfall Extremes (Table J)

Very often a plantation management wants to know the dependability of rainfall or how much rain to expect in a particular month or season. The arithmetical average of the data recorded is not always a safe guide. From the table of rainfall extremes (Table J), we see that at Pepeekeo the rainfall extremes for the month of August are 29.75 inches and 4.06 inches. It is just as possible to get 29 inches rain as 4 inches.

But for practical purposes, we want to know not what it is possible to get but the average expectancy of rainfall. For such purposes, it will be found advisable to study the distribution of rainfall in any particular month or season for the years of which we have record. We see that at Pepeekeo, for the month of August, in about 80 per cent of the years on record, rainfall varied between 5 inches and 15 inches, the mean of these years being 13 inches. Therefore, we would be justified in assuming that our chances are 8 to 10 that we shall get an average rainfall of 13 inches in August. In the case of Pepeekeo, this mean comes close to the arithmetic mean, but in some other cases, like Honokaa Mill, it will be found that the average expected rainfall is only two-thirds of the arithmetic mean.

As we have observed previously, it may be found of greater advantage to similarly study the seasonal variations and expectancy of total rainfall. Table K gives the seasonal rainfall extremes for Pepeekeo. It will be noted that seasonal variations are less than monthly variations.

TABLE H

* NORMAL MONTHLY RAINFALL OF ALL THE PLANTATIONS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual	Period Included in the Normals
OAHU														
Ewa	2.82	3.40	2.61	1.33	0.81	0.57	0.37	0.59	0.91	1.15	2.29	3.90	20.75	1891-1928
Kahuku	4.23	4.40	4.84	3.22	2.04	1.63	1.90	2.16	2.23	2.79	3.50	4.68	37.62	1891-1928
Waialua	4.34	3.93	3.80	2.72	1.34	0.94	1.07	1.06	1.47	1.52	3.08	5.49	30.76	1901-1928
Waianae	2.93	3.36	2.27	1.31	0.78	0.45	0.32	0.73	0.96	0.92	2.18	3.57	19.78	1891-1928
Waimanalo	5.81	5.09	5.86	4.46	2.57	1.54	1.33	1.61	1.79	2.53	4.49	6.15	43.83	1895-1928
Waipahu	3.66	3.38	3.36	1.59	1.27	0.72	0.46	0.85	0.99	1.48	2.19	4.36	24.31	1898-1928
KAUAI														
Eleele	4.82	2.85	4.33	2.03	1.53	1.08	1.29	1.00	1.88	2.00	2.58	4.14	29.63	
Grove Farm	5.61	4.46	5.92	3.32	3.28	2.13	2.49	2.65	3.24	3.76	5.39	5.88	48.13	1885-1928
Kealia	4.75	3.33	5.60	2.89	2.29	1.71	2.01	1.81	2.72	3.30	4.08	5.42	39.91	1899-1928
Kekaha	3.70	2.75	3.42	1.23	0.95	0.55	0.56	0.80	1.10	1.38	2.15	3.69	22.28	1890-1928
Kilauea	6.51	5.31	8.79	5.68	5.03	3.73	4.63	4.57	4.90	5.34	7.14	7.09	68.72	1885-1928
Koloa	7.01	4.79	6.75	4.96	4.75	3.98	4.64	4.70	4.56	5.16	6.12	6.75	64.17	1887-1928
Lihue	7.25	3.46	6.23	3.93	3.50	2.48	2.93	3.05	4.24	4.20	5.10	6.80	53.17	1905-1928
Makaweli	3.58	2.46	3.71	1.24	1.09	0.81	0.69	0.56	1.20	1.45	2.25	3.77	22.81	1896-1928
MAUI														
Lahaina	2.73	1.27	1.90	1.33	0.41	0.10	0.08	0.06	0.29	0.40	0.64	2.92	12.13	1914-1928
Wailuku	4.97	3.55	3.83	3.53	1.38	0.56	0.70	0.95	0.87	1.18	2.38	5.04	28.94	1902-1928
Kaanapali	3.70	2.70	2.05	1.60	0.71	0.27	0.43	0.86	0.45	0.63	1.28	3.62	18.30	1892-1928
HAWAII														
Hakalau	13.50	9.46	15.15	13.59	9.85	8.52	10.74	13.73	12.18	10.54	14.97	14.81	147.04	1905-1930
Hilo	12.36	8.92	15.38	12.13	9.16	8.20	9.80	13.14	11.87	11.03	14.56	14.48	141.03	"
Honokaa	7.82	6.87	8.81	9.46	4.93	3.32	4.63	6.25	4.14	3.36	9.47	9.42	78.48	"
Kohala	5.53	4.20	4.97	6.59	4.21	3.79	4.89	5.41	3.89	2.97	6.00	6.11	58.56	"
Naalehu	5.32	3.88	4.71	3.39	2.03	1.55	1.83	3.19	2.91	3.71	4.75	5.87	43.14	"
Niulii	5.64	4.24	5.77	6.75	4.49	3.87	5.20	5.73	4.24	3.15	6.08	6.77	61.95	"
Olaa Mill	11.78	8.89	14.16	13.63	9.33	7.96	10.24	12.74	10.93	10.45	14.79	16.16	141.06	"
Ookala	10.36	8.68	12.55	13.67	8.10	6.20	8.89	11.48	7.30	7.06	12.14	12.26	118.69	"
Paauhau	6.99	6.00	7.87	8.19	4.72	2.95	4.33	5.74	3.73	3.00	8.10	8.08	69.70	"
Paauilo	8.95	7.14	10.45	11.33	6.23	4.31	6.10	8.06	5.45	4.03	10.29	12.55	94.89	"
Pahala	5.82	4.10	5.78	3.54	2.30	1.07	1.37	3.00	2.40	3.86	5.21	5.81	44.26	"
Papaikou	16.62	11.25	19.42	17.15	12.45	10.61	13.45	16.60	14.82	12.90	18.60	19.00	182.87	"
Pepeekeo	12.44	8.07	11.66	11.91	8.59	7.39	9.30	11.30	11.33	9.62	12.80	13.83	128.24	"
MAUI														
Hana	8.56	5.42	7.54	9.42	4.57	3.77	4.31	5.36	5.22	4.90	6.67	9.47	75.21	"

* The normals for the irrigated plantations include records up to 1928 and were obtained from the files of the U. S. Weather Bureau at Honolulu.

TABLES—I

RAINFALL DEPARTURES FROM NORMAL BY MONTHS

STATION HAKALAU

Data—Rainfall Departures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— 5.59	— .70	— 2.74	— 6.12	+ 3.82	+ .11	+ 1.65	+ 3.26	+ 7.13	— .55	+22.36	— 2.14
1906....	— 7.24	— 7.27	— 9.08	— 4.96	+ .99	— .35	+ .39	+ 8.31	— 3.59	— 6.54	+ 2.88	+ 2.22
1907....	— 5.36	+ 7.82	— .65	— 4.84	— .50	+ 2.68	— 1.51	+19.61	+25.13	+ 3.93	— 2.44	— 8.31
1908....	— 6.05	+14.57	— 8.65	+ 4.67	— 1.60	— 2.20	+ 1.14	— 3.33	+ 2.25	+ 2.75	— 4.39	+ .99
1909....	— 5.76	+ 2.65	+19.58	+ 2.01	+ .21	— 1.93	+ 6.59	— 7.96	— 3.47	— 2.21	—10.64	+ 6.43
1910....	+ 4.03	— 3.89	+ 1.21	— 3.80	— .50	+ 4.20	+ .25	+ 1.10	— 4.50	— 5.20	— 5.56	+ 4.94
1911....	+ 5.44	+13.67	— 4.06	+ 3.25	+ 5.39	+ 6.60	— .24	— .89	+ 7.75	+ 3.62	— .77	— 2.41
1912....	—11.21	+ 5.91	— 2.82	+13.37	— 3.33	+ .74	— 1.56	— 2.45	— 5.37	+ 6.60	+ 4.84	+ 5.42
1913....	+18.84	— 4.51	— 8.25	— 1.27	— 2.36	+ 1.21	— 3.12	— 3.24	— 6.60	— 3.46	+10.87	— 6.17
1914....	— 4.97	— 6.53	— 3.01	— 1.88	+20.31	+10.34	+ 7.14	+23.48	+16.13	+ 1.38	+ 3.30	— 3.23
1915....	— 9.39	— .15	—11.37	+ 8.82	— 6.70	+ 1.89	— 1.83	— 9.12	— 4.53	+ 2.86	+31.52	— 2.45
1916....	+ .32	— 7.54	— 2.55	— 4.55	+16.64	+ 3.52	— 1.45	+ 5.02	— .29	+ 2.68	— 2.74	+19.24
1917....	+10.22	— 5.81	+ 3.40	— 3.08	— 3.66	— .19	— 4.29	—10.82	— 9.62	— 7.48	— 1.40	— 8.42
1918....	+ 7.01	+15.25	+13.35	+13.61	+ 5.49	+ 3.31	+16.61	— 3.02	— 4.79	— 2.75	— 4.44	+ 2.66
1919....	— 7.41	— 4.07	— 4.53	— 9.27	— 3.85	— 3.92	— 4.40	— 4.13	— 1.07	— 3.24	— 7.20	—10.59
1920....	— 7.11	— 4.71	+13.36	— 7.72	— 9.62	— 5.81	— 2.88	— 6.76	— .19	+ 9.71	— 6.43	— 9.29
1921....	+22.44	— 6.87	— 7.55	— 4.97	— 7.55	— 5.50	— 2.02	— 1.19	— 5.79	— .03	+ 7.68	+ 5.14
1922....	+10.69	+10.98	+28.72	+ 1.43	— 3.17	— 6.75	— 4.73	— 6.21	+ 3.67	— 2.47	+ 3.24	—10.49
1923....	+26.47	— .45	+ 9.90	+13.86	+ 1.73	+ 1.18	+ 1.42	— .40	+ 6.94	+ 4.55	— 8.38	+18.79
1924....	— 9.85	— .14	— 7.85	+ 6.28	— 4.18	— 4.70	+ 2.41	— 2.80	— 4.86	+19.51	— 8.79	—11.90
1925....	— 3.57	— 8.23	+11.27	— 3.62	+ .95	+ .79	— 7.05	+ 1.94	+ .01	— 5.58	— 3.24	—13.65
1926....	—10.05	— 3.79	—13.61	— 9.98	— 3.92	— 6.05	— 6.41	+ 3.02	— 7.19	— 5.23	—10.96	— 3.20
1927....	— 1.02	— 7.18	+ .23	— 2.26	+ 1.41	— 2.50	— .01	— .20	— .39	— 4.45	— 3.72	+28.94
1928....	— 5.20	— 4.48	—11.32	— 8.22	— 3.28	— .96	+ 2.30	— 4.76	— .02	+ .25	— 8.20	+ 3.89
1929....	— 1.38	+ 5.91	— 1.40	— 3.84	— 5.60	— 4.52	+ 4.67	— 4.01	— 7.42	— 4.73	— 1.89	+ 3.41
1930....	— 4.34	— 1.25	— 1.55	+13.09	+ 2.95	+ 8.87	— 3.18	+ 5.57	+ .57	— 4.17	+ 4.47	— 9.91
Means..	13.50	9.46	15.15	13.59	9.85	8.52	10.74	13.73	12.18	10.54	14.97	14.81

Annual—147.04

HILO STATION

Data—Rainfall Departures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—11.37	— 3.89	— 8.63	— 6.07	— 1.56	— .86	+ .21	— 1.03	+ 6.98	— .94	+11.30	— 2.73
1906....	— 8.82	— 6.93	—13.63	— 3.81	+ .09	— 2.19	+ 4.72	+ 7.48	— 4.76	— 6.45	+ 3.36	— 2.83
1907....	— 6.67	+ 2.33	— 1.44	— 6.63	— 4.40	+ 2.79	+ .61	+24.63	+14.41	+ 5.83	— 3.82	— 9.03
1908....	— 3.38	+13.08	— 7.33	+ 3.21	+ .02	— 1.92	— 1.84	— 3.93	+ 1.41	— .23	— 7.87	+ 1.10
1909....	— 5.49	+ 1.10	+14.15	— 4.68	+ 1.63	— .73	+ 4.37	— 8.06	— 4.07	— 2.38	—10.47	+ 2.61
1910....	+ 3.53	— 6.05	+ 2.35	— 1.73	+ 3.86	+ 4.01	+ .64	+ 5.04	— 7.91	— 8.39	— 4.62	+ .88
1911....	+ 3.43	+ 9.81	— 1.52	+ 6.07	+ 6.40	+ 3.09	— 3.77	— 2.95	+11.10	— 3.69	— 1.14	+ .53
1912....	—12.10	+ 6.91	+ .57	+ 2.31	— 1.47	— 1.76	— 3.38	— 8.65	— 4.74	+ 7.51	+ .04	+ 3.05
1913....	+21.27	— 3.16	— 6.48	— .41	— 3.70	+ 4.32	— 2.66	— 5.45	— 5.48	— 5.63	+16.84	— 6.18
1914....	— 5.34	— 4.53	— 9.00	— 1.01	+11.32	+17.27	+13.65	+15.07	+12.19	+ .46	+ 3.70	— .58
1915....	— 9.00	+ .31	—12.76	+ 9.77	— 5.29	+ .98	— 3.46	— 8.06	— 2.17	+ 9.69	+14.20	— 5.25
1916....	+ 4.08	— 4.59	— 6.06	— .30	+12.30	+ 1.75	— 1.02	— .60	+ 1.51	+ .34	+ .86	+ 8.58
1917....	— 3.91	— 4.98	+ 3.77	+ .07	— 1.10	— 3.62	— 5.03	—10.72	— 9.37	— 6.58	— .37	— 8.01
1918....	+ 1.53	+20.51	+ 6.40	+ 4.55	+ 5.31	+ 3.20	+ 7.72	+ .97	— 5.28	— 3.57	+ 4.03	+ 5.31
1919....	— 6.80	— 3.02	— 3.76	— 8.22	— 3.85	— 2.85	— 2.34	— 1.12	+ 2.64	+ .15	— 3.07	—10.59
1920....	— 8.11	— 4.20	+11.93	— 3.30	— 7.85	— 4.46	— 2.62	— 5.13	— .34	+ 9.33	— 7.29	— .99
1921....	+ 3.84	— 3.84	—10.94	— 1.64	— 6.80	— 5.26	— 2.26	— 2.60	— 4.47	+ 2.87	+12.64	+ 1.36
1922....	+ 9.29	+10.03	+51.58	+ .98	— 1.47	— 5.88	— 4.46	— 5.92	+ 4.62	— 1.82	+ 2.76	—11.35
1923....	+29.24	— 1.41	+ 9.97	+10.71	+ 1.05	— .48	— .27	+ .26	+ 5.03	+ 2.04	— 7.74	+17.87
1924....	— 9.90	— .58	— 7.90	+ 7.04	— 1.14	— 4.76	+ 3.20	+ .34	— 3.95	+14.05	— 5.70	—10.94
1925....	+ 1.40	— 7.00	+10.26	+ 1.55	+ 1.06	+ .40	— 4.86	+ 5.32	— 3.23	— 3.67	— 3.30	—13.16
1926....	— 8.52	— 3.06	—13.34	—10.13	— 1.28	— 4.56	— 4.42	+ 4.14	— 3.25	— 4.13	—11.78	+ .98
1927....	+ 1.16	— 6.68	+ 4.10	— 1.73	+ 3.12	— 1.28	+ 1.80	+ 1.58	+ .67	— 2.87	— 1.96	+37.40
1928....	— 4.56	— 3.30	—10.84	— 6.09	— .53	— 1.16	+ 3.50	— 4.99	+ 2.11	+ 6.49	— 7.67	+ 9.52
1929....	— 3.92	+ 6.23	+ 2.04	— 1.29	— 6.72	— 4.63	+ 2.89	— 4.79	— 6.95	— 6.74	+ 3.00	+ .82
1930....	— 5.99	— 4.00	— 3.53	+10.32	+ 1.09	+ 8.42	— .80	+ 9.66	+ 3.22	— 1.73	+ 4.04	— 8.47
Means..	12.36	8.92	15.38	12.13	9.16	8.20	9.80	13.14	11.87	11.03	14.56	14.48

Annual—141.03

HONOKAA MILL STATION

Data—Rainfall Departures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— 2.51	— 3.66	+ 1.57	— 1.03	+ 2.02	+ .40	+ 1.19	+ .28	+ 7.92	+ 1.36	— 3.94	— 2.93
1906....	— 6.28	— 6.03	— 6.18	— 1.64	— 2.09	— 2.10	+ 2.45	+ 2.23	— 2.62	— 2.32	— 5.97	+ 8.82
1907....	— 4.93	+ 1.84	+ .36	— 4.07	— 3.45	— 1.01	+ 3.29	+11.60	+ 3.08	+ 4.79	— 4.61	— 6.22
1908....	— 4.19	— 3.07	— 2.94	— 5.32	— 2.88	— 1.41	+ 2.19	+ .98	+ 3.45	+ .39	+ .40	+ 2.69
1909....	— 2.28	+ .28	+ 5.14	+ 2.42	— 1.83	— 1.42	+ .13	— 5.23	— 2.01	— 1.12	— 6.90	— 2.80
1910....	+ 2.48	+ .01	— 3.08	— 3.23	+ 2.92	+ 2.80	— .29	— .59	— 3.16	+ 2.51	— 1.63	+ 6.59
1911....	+ 1.62	+13.24	— 2.04	— 1.52	+ 2.81	+ 3.97	— 1.86	— 1.51	+ 3.54	— .82	— 2.52	— 3.92
1912....	— 6.43	+ 1.26	— .65	+ 1.01	— 2.84	— 1.36	— 3.68	— 3.71	— .45	+ .94	— 1.65	— 6.15
1913....	— 5.41	— 2.30	— 6.48	— 3.63	— .82	— .77	— 2.83	— 2.16	— 2.38	— 3.16	+ 3.91	+10.05
1914....	+ 5.31	— 3.96	+ 1.72	— .69	+13.73	+ 4.46	+14.82	+18.01	+ 3.33	+ 1.01	+ 5.51	— .07
1915....	— 4.31	+ 2.18	— 4.77	+ 3.98	— 2.30	+ 2.20	— 1.24	— 5.88	— .78	+ 2.70	+ 1.96	— 3.28
1916....	+ 5.18	— 6.30	— .65	+ 2.96	+12.29	+ 1.06	— 2.05	— 2.10	— .78	— 1.28	— 5.58	+ 4.95
1917....	— 4.21	— 2.95	— 6.98	— 8.10	— 3.85	— 1.36	— 3.65	— 6.10	— 1.01	— 2.58	— 1.49	— 7.10
1918....	+ .53	+17.45	+ 4.76	+28.17	+11.14	+ 5.00	+ 5.44	+ .30	— 3.23	— .16	+ 1.57	+ 8.32
1919....	— 2.06	— 5.21	+ .62	— 5.81	— 1.04	— 3.07	— 2.69	— 1.98	— 3.78	— 3.11	— 7.91	— 1.91
1920....	— 4.60	— 4.72	+ 4.62	— 6.44	— 4.88	— 3.13	— 3.33	— 2.22	— 1.54	— .29	— 5.41	— 5.83
1921....	+11.18	— 6.12	+ 3.59	— 5.67	— 4.56	— 3.10	— .02	— 3.11	— 2.52	+ 1.34	+15.32	+ 4.71
1922....	+ 2.53	+ 1.37	+ 6.73	— 7.32	— 3.51	— 2.89	— 4.18	— 5.21	+ 4.76	— 2.05	— 1.05	— 9.20
1923....	+ 5.59	— 2.21	+ 7.18	— 4.69	— 2.75	— 1.15	— 1.32	+ 5.52	+ 3.4	+ 3.01	— 5.70	+ 9.43
1924....	— 6.39	+ 1.31	— 4.38	— 2.88	— 2.01	— 2.33	— 2.57	— 3.13	— 2.30	+ 2.24	— 2.95	— 8.65
1925....	— 2.43	— 5.61	+ .63	— 2.86	— 1.31	— .80	— 3.13	+ 1.51	— 1.99	— 1.23	— 6.44	— 8.96
1926....	— 6.61	— 4.21	— 7.40	— 1.15	— 3.40	+ 1.37	— 2.34	— 1.24	— 1.45	+ 2.38	— 4.24	— 7.43
1927....	+ 2.80	— 4.59	— 6.71	+ 1.97	— 4.07	— 2.24	+ 2.36	— 3.06	— .36	— 1.03	— 1.33	— 1.49
1928....	— 4.09	— 3.82	— 5.03	— 7.71	— .36	— 1.32	+ 1.20	— 3.74	+ .15	— 2.04	— 2.91	— 1.63
1929....	+ 4.21	+ 8.11	+ 1.50	— 1.17	— 2.18	— 2.19	— 2.13	+ .02	— 3.80	— 2.88	+ 4.18	+ 8.12
1930....	+ 2.71	— 2.00	— .12	+ 8.42	— 1.01	+ 2.97	— 1.46	— .99	+ 1.50	— 1.20	+ 8.19	— 6.55
Means..	7.82	6.87	8.81	9.46	4.93	3.32	4.63	6.25	4.14	3.36	9.47	9.92

Annual—78.98

KOHALA MILL STATION

Data—Rainfall Departures from Normal

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— 3.54	— 1.79	+ 1.72	— 1.28	+ 2.06	— 1.03	— 1.68	+ .94	+ 3.49	+ 1.04	— 1.48	— .03
1906....	— .88	— 2.32	— 1.67	+ 1.77	+ .45	— 1.82	+ 2.88	+ .97	— .67	— .75	— 1.18	+ 8.85
1907....	— 2.79	+ 4.53	+ .23	— 2.80	— 2.48	— .26	— .61	+ 2.96	+ 3.96	+ 1.78	....	+ 4.30
1908....	— 3.43	— .95	— 3.06	— 3.35	+ 1.02	+ 1.80	+ 2.82	+ .90	+ 1.81	+ .21	— 2.29	+ 1.06
1909....	— 1.88	+ 1.81	+ 3.12	— 1.68	+ .16	— 1.53	+ 2.58	— 4.72	— .42	— .97	— 2.38	— .11
1910....	+ 1.02	— 2.07	+ 1.87	— 1.66	+ .07	+ 1.63	+ 2.36	— .53	— 2.20	+ 1.21	— 1.49	+ 3.02
1911....	+ 2.45	+ 3.83	+ 2.24	+ .37	— .64	+ 4.28	— 1.19	— 1.09	+ 2.79	— .40	— .41	— 3.84
1912....	— 4.67	+ .95	— .85	+ 2.27	— .70	— .78	— 2.41	— 3.34	— 1.71	+ .96	— .25	— 2.57
1913....	— 1.63	— .20	— 2.63	— 1.21	+ .55	+ 1.78	— 1.61	— .81	— 1.78	— 2.00	+ 1.83	— .17
1914....	+ .17	— 3.66	— .38	— 2.62	+ 7.00	+ 7.06	+ 7.73	+13.02	+ 3.79	+ 2.62	+ 4.97	+ 1.54
1915....	— 2.98	+ 1.28	— 2.83	+ 2.23	— 2.85	— 1.33	— 1.62	— 3.84	— .62	+ 2.45	+ 4.23	— .55
1916....	+ 7.85	— 3.71	+ .27	+ 2.21	+ 8.19	+ 3.84	+ .70	+ 1.65	+ .37	— .99	— 4.09	+ 3.28
1917....	— .10	— 1.34	— 1.21	— 4.78	— 1.94	— 1.89	— 3.60	— 4.38	— 3.51	— 1.96	— .25	— 4.08
1918....	+ 2.82	+ 6.48	+ 2.73	+12.19	+ 6.69	+ 3.90	+ 6.86	+ 1.92	— 2.75	+ .61	+ .91	+ 6.88
1919....	— 2.89	— 2.55	+ .22	— 2.79	— 1.74	— 1.34	— 1.46	+ .41	— .02	— 1.35	— 4.87	— .65
1920....	— .64	— 2.15	+ 1.23	— 2.27	— 3.49	— 3.11	— 2.87	— .99	— .04	— .29	— 2.45	— .32
1921....	+ 8.02	— .95	+ 1.65	— 1.74	— 3.53	— 2.32	— .09	— .94	— .39	+ .57	+ 7.02	+ 4.85
1922....	+ 2.66	+ 1.51	+ 6.43	— 1.61	— 1.44	— 3.02	— 2.65	— 1.39	+ 4.74	— 1.22	+ 1.24	— 4.87
1923....	+ 9.57	— 3.02	— .01	+ 4.24	— 1.42	+ 1.28	— .14	+ .32	— .26	+ 1.00	— 1.79	+ 2.86
1924....	— 3.47	+ 2.64	— 1.78	+ 1.94	— 1.93	— 2.75	— 1.42	+ .43	— 1.37	+ 2.76	— .88	— 2.22
1925....	— .94	— 2.67	+ 1.52	— .54	+ .94	+ .10	— 1.98	+ 1.21	— 1.78	— 1.17	— 3.34	— 5.35
1926....	— 3.37	— .87	— 3.77	— 2.75	— 1.10	— 1.66	— .56	— .21	— .93	— .94	— 2.76	— 4.55
1927....	— .72	— 1.36	— 1.66	+ 4.06	— 1.62	— 1.32	+ .38	+ .83	— .22	— .34	— 1.29	+ 8.44
1928....	— 1.34	— 1.22	— 3.37	— 3.16	— .27	— 1.22	+ .48	— 2.38	+ 1.88	— 1.47	+ .56	+ 1.40
1929....	+ .42	+ 3.78	+ .21	— 2.07	— 1.86	— 1.78	— 1.54	— 2.43	— 3.51	+ .71	+ 3.63	+ 4.54
1930....	+ .22	+ 3.91	— .17	+ 5.08	— .03	+ 1.54	— 1.33	+ 1.55	— .90	— .79	+ 7.92	— 3.06
Means..	5.53	4.20	4.97	6.59	4.21	3.79	4.89	5.41	3.89	2.97	6.00	6.11

Annual—58.56

NAALEHU STATION

Data—Rainfall Departure

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— 4.86	— 3.20	— 3.96	— 2.78	— .89	— .29	+ .66	— .59	+ .62	— 1.54	+ 2.94	— 3.33
1906....	+ .2	— 3.44	— 4.47	— 2.78	+ .67	— .21	— .63	+ 2.35	— 2.24	— 2.37	+ 9.20	+ .95
1907....	+ 4.62	+ 3.34	— .18	— 1.95	— .03	+ 2.70	+ .24	+ 8.45	+ 8.58	+ .67	— 4.12	— 5.10
1908....	— 3.99	+ .24	+ 2.3	— 0.94	— 1.63	— 1.31	— 1.29	— 1.48	— 1.01	— 2.26	— 4.32	— 5.41
1909....	— 4.92	+ .49	+ 2.3	— 1.72	+ .01	— .77	— .56	— 3.08	— 1.68	+ 1.56	— 4.34	+ 7.57
1910....	+ 1.69	— 2.57	— 1.97	— 2.00	— 1.33	— .06	— .62	+ 4.45	+ .55	— 1.87	— 1.43	— 4.18
1911....	— .34	+ 4.97	+ 7.14	+ 1.14	+ .19	— .11	— 1.7	— 1.25	— 1.55	+ .13	— 2.15	— 1.52
1912....	— 4.69	+ .47	— 2.32	— 2.33	— .88	+ .73	+ 2.4	— .77	— 1.82	+ 2.20	— 4.16	— 3.51
1913....	+ 1.75	— 1.41	— 3.29	— 2.94	+ 3.85	+ 1.65	— 1.27	— .94	— 1.38	— 1.51	+ 9.87	— 2.55
1914....	— 1.55	— 2.20	— .16	— 2.10	+ 1.56	+ 3.23	+ 2.71	+ 3.21	+ 1.59	— .59	+ 2.61	+ 1.71
1915....	— 5.29	— 1.81	— 4.51	— .33	— .56	+ 1.19	+ 2.85	— 1.90	— 2.47	+ 5.14	+10.04	+ 3.53
1916....	+ 8.94	— 3.10	+ 6.61	— .67	+ 2.43	— 1.53	— 1.15	— 1.60	— 1.46	+ .56	— 3.05	+ 9.92
1917....	+ 6.67	— .67	+ 9.05	+ .41	— .35	— .52	— 1.61	— 2.87	— 2.79	— 1.56	— 3.85	+ 2.34
1918....	+ 7.29	+16.16	+ .48	+ 5.17	— .91	+ .87	+ 2.70	+ .04	— 1.48	— 2.27	+ 3.69	— 5.47
1919....	— 4.25	— 3.76	— 3.41	— 1.45	— .60	— .37	— 1.51	— 2.53	+ .28	+ 1.73	— .34	— 1.88
1920....	— 1.23	— 2.54	+ .16	— 1.84	+ 1.49	— .54	— 1.01	— 2.41	— .55	— 1.34	— 4.20	+ .83
1921....	+11.10	+ .12	— 1.53	— 1.75	+ .05	— 1.10	— .91	— .22	— .80	— 2.03	— 3.67	— 3.33
1922....	+ 1.66	+ 6.55	— 2.14	— 1.90	— 1.46	— .94	+ .86	— 2.13	— .75	+ .87	— 2.00	— 3.13
1923....	+ 9.25	+ 4.09	+ 4.88	+13.95	+ .11	— .35	— 1.41	+ .97	+ 1.67	— 2.37	— 2.67	+ 1.35
1924....	— 4.65	— 3.22	— .20	+ 9.61	+ .90	— .12	+ .78	— 1.31	+ 1.48	+ 1.95	+ 3.72	— 1.05
1925....	— 3.94	— 3.14	+ 2.76	— 2.58	— 1.52	+ .58	— .32	— 1.47	— .67	— .40	— 1.82	— 2.31
1926....	— 3.79	— 3.63	— 4.03	— 2.74	+ .25	— .77	— .83	+ 5.19	— 1.80	+ 1.60	— 2.39	+ 4.43
1927....	— 3.18	— 2.98	+ 3.38	+ 6.10	— .68	+ .16	— 1.11	+ 2.48	+ 6.45	+ .39	— 3.16	+19.84
1928....	— 4.81	— 2.44	— 2.52	— .76	— .04	— .77	+ 3.07	— 1.29	+ .43	+ .59	— 3.05	— 3.09
1929....	+ .54	+ 5.90	— 1.63	— 1.14	— .15	— .98	— .01	— 1.46	— 1.03	— 1.68	+ 9.98	— 1.39
1930....	— 1.99	— 3.16	+ 1.62	— 1.72	— .63	— .28	+ .28	+ .24	+ 1.86	+ 4.39	— 1.41	— 5.26
Means..	5.32	3.88	4.71	3.39	2.03	1.55	1.83	3.19	2.91	3.71	4.75	5.87

Annual—43.14

NIULII STATION

Data—Rainfall Departures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— 2.96	— 2.00	+ 1.13	— .61	+ 2.29	— .85	— .71	+ 1.10	+ 4.10	+ 1.19	— .92	— 1.30
1906....	— .75	— 2.36	— 2.38	+ .87	+ .16	— 1.86	+ 2.99	+ 1.37	— .89	— 1.65	— 1.47	+ 7.51
1907....	— 2.50	+ 3.13	+ .96	— 3.07	— 1.86	— .57	+ .31	+ 2.39	+ 3.70	+ 1.48	— .46	— 4.63
1908....	— 3.64	— 1.00	— 3.16	— 3.93	+ .04	+ 1.03	+ 2.94	+ 1.43	+ 1.29	— .29	— 2.47	+ .79
1909....	— 2.50	+ 1.40	+ 4.13	+ .45	+ .53	— 1.39	+ 1.40	— 4.86	— 1.11	— .75	— 2.49	— .26
1910....	+ 2.27	— 1.61	+ 2.05	— .90	— .14	+ 1.54	+ 3.75	— .47	— 2.33	+ 1.23	— 1.21	+ 5.12
1911....	+ 2.36	+ 4.46	+ 1.67	+ 1.14	— .70	+ 4.69	— 1.37	— .82	+ 3.99	+ .02	+ .47	— 4.55
1912....	— 4.63	+ 1.28	— .46	+ 2.73	— .42	— .33	— 2.49	— 3.12	— 2.13	+ 2.15	— .23	— 3.31
1913....	— 2.45	— 1.35	— 3.52	— 1.18	— .35	+ .97	— 2.10	— 1.33	— 1.32	— 2.24	+ 1.12	+ 1.11
1914....	+ .46	— 3.72	— .20	— 2.91	+10.07	+ 7.69	+ 9.58	+13.79	+ 4.96	+ 2.99	+ 5.93	+ 3.29
1915....	— 2.58	+ .97	— 3.60	+ 3.10	— 3.38	— .60	— .90	— 3.99	+ .42	+ 2.38	+ 2.51	— 1.47
1916....	+ 4.38	— 3.86	— .87	+ 2.63	+ 6.75	+ 2.68	+ 1.27	+ 2.13	— .22	— .99	— 3.52	+ 4.48
1917....	— .55	+ 1.27	— 2.07	— 4.78	— 2.28	— 1.89	— 3.86	— 4.48	— 3.65	— 2.15	— .17	— 4.77
1918....	+ 1.81	+ 5.53	+ 3.65	+12.05	+ 6.95	+ 3.59	+ 6.23	— .01	— 3.17	+ .95	+ 1.01	+ 8.34
1919....	— 1.90	— 2.79	+ .50	— 3.04	— 2.00	— 2.61	— 2.04	— .10	— .61	— 1.65	— 4.97	— .25
1920....	— 1.28	— 2.53	+ 2.70	— 2.49	— 4.01	— 3.11	— 3.38	— 1.21	— .35	— 1.25	— 3.01	— 2.54
1921....	+ 5.49	— 2.12	+ 2.06	— 2.05	— 3.58	— 2.93	— .79	— 1.32	— .90	+ .71	+ 7.86	+ 3.46
1922....	+ 2.72	+ .57	+ 6.15	— 1.59	— 2.29	— 2.94	— 3.36	— 2.34	+ 5.28	— .90	+ .13	— 5.60
1923....	+12.42	— 3.23	+ 2.15	— .30	— 1.72	+ 1.50	— .30	+ .70	+ .46	+ 2.26	— 1.81	+ 2.02
1924....	— 4.09	+ 3.00	— 2.96	+ 3.22	— 1.74	— 2.72	— 1.22	+ 1.08	— .75	+ 2.83	....	— 3.88
1925....	+ .52	— 3.05	+ 3.02	— .96	+ 1.42	+ .48	— 3.24	+ .97	— 1.94	— 2.02	— 4.16	— 6.33
1926....	— 3.09	— .58	— 4.81	— 2.24	— 1.27	— 1.73	— 1.15	+ .27	— .82	— .69	— 3.52	— 4.99
1927....	— .63	+ .36	— 3.32	+ 2.98	— 1.74	— 1.30	+ 1.09	+ .96	— .53	— .29	— .25	+ 5.68
1928....	— 1.55	— .26	— 4.28	— 3.85	+ .35	— .58	+ .90	— 1.97	+ 1.48	— 1.99	+ 1.50	+ 1.70
1929....	+ 1.91	+ 4.83	+ .13	— 1.96	— .79	— 1.30	— 1.91	— 2.09	— 3.91	— 1.21	+ 2.26	+ 4.83
1930....	+ 1.26	+ 3.54	+ 1.24	+ 6.64	— .29	+ 2.53	— 1.71	+ 1.92	— 1.00	— .17	+ 7.92	— 4.41
Means..	5.64	4.26	5.77	6.75	4.49	3.87	5.20	5.73	4.24	3.15	6.08	6.77

Annual—61.95

OLAA MILL STATION

Data—Rainfall Departures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905	— 9.79	— 2.75	— 9.38	— 4.84	+ 1.98	+ .12	+ 3.40	+ 2.18	+ 5.34	+ 6.39	+15.47	+ 1.67
1906	— 5.74	— 5.33	—11.75	— 5.03	— .71	+ .03	+ 2.17	+ 7.22	— 1.58	— 5.15	+ 3.48	— 1.59
1907	— 8.00	+ 4.90	— 1.58	— 9.04	— 4.12	+ 2.25	— .20	+20.09	+10.96	+ 9.42	— 4.74	—10.96
1908	— 3.70	+15.35	— 8.09	+ 4.18	— 1.06	— 1.67	— 2.96	— 2.42	— .07	— .62	— 7.82	— 1.19
1909	— 5.30	+ 1.88	+15.94	— 4.45	+ 1.80	— 1.84	+ 3.21	— 7.25	— 2.81	— 1.40	—11.61	+ 3.22
1910	+ 8.30	— 3.42	— 1.82	— 3.92	+ 2.03	+ .95	+ .57	+ 1.63	— 5.52	— 2.45	— 3.90	+ 1.76
1911	+ 1.95	+10.18	— 1.01	+ 6.12	+12.65	+ 3.32	— 3.17	— 3.07	+ 3.36	— 3.22	— .97	— 1.10
1912	—10.72	+ 4.56	+ 1.91	+ 2.03	— 2.97	+ .06	— 1.92	— 7.54	— 1.79	+ 9.35	— .68	+ 4.23
1913	+17.45	— 3.75	— 8.26	+ 2.34	— 2.28	+ 2.73	— 2.29	— 1.20	— 5.78	— 4.48	+15.67	— 5.70
1914	— 5.73	— 4.04	— 5.78	— 6.16	+ 8.58	+17.79	+ 8.82	+21.44	+12.04	— 4.17	+ 1.83	+ 4.71
1915	— 7.36	— 1.64	—10.53	+ 7.47	— 4.67	+ .47	— .37	— 7.60	— .53	+ 7.64	+22.29	+ 5.71
1916	+ .18	— 5.69	— 2.19	+ 3.35	+ 4.63	+ 2.94	— 2.14	— .87	+ .51	+ 2.78	+ 1.45	+23.80
1917	+ 2.53	— 6.44	+13.33	+ 2.40	+ 1.59	— .63	— 4.06	— 8.97	— 7.77	— 6.99	+ 4.33	— 8.10
1918	+10.53	+22.38	+11.66	+14.41	+ 4.43	+ 1.16	+12.22	— 1.03	— 5.06	— 3.02	+ 1.07	+ .21
1919	— 7.20	— 1.83	— 4.41	— 8.28	— 3.83	— 4.17	— 5.58	— 3.94	— 6.03	+ 1.26	— 8.59	—11.72
1920	— 4.95	— 4.13	+ 8.82	— 7.67	— 7.53	— 4.00	— 4.62	— 4.62	— 1.06	+ 2.61	— 5.91	— 7.30
1921	+17.39	— 3.26	—10.03	— 2.58	— 6.26	— 4.85	— 1.51	— 3.88	— 3.59	+ .88	+ 4.83	— 2.84
1922	+15.44	+ 4.04	+30.40	+ .38	— 1.23	— 5.92	— 4.73	— 3.96	+ 5.20	— 4.58	+ 4.84	—13.03
1923	+26.08	+ 3.65	+ 9.37	+ 8.32	+ 1.07	+ .18	+ 1.76	— 2.35	+ 3.92	+ 2.66	— 9.25	+13.34
1924	— 8.75	— 1.14	— 5.12	+10.48	— 3.93	— 4.01	+ 5.36	— 2.72	— 1.48	+ 9.02	— 7.27	—12.11
1925	+ 3.04	— 7.35	+ 8.31	— .34	+ .55	— .41	— 5.63	+ 3.86	— 1.10	— 6.14	— 2.26	—14.55
1926	— 7.85	— 1.71	—11.85	—11.69	— 1.12	— 5.84	— 6.03	+ 4.43	— 1.78	— 4.49	— 9.51	+ 2.26
1927	— .28	— 6.43	+ 2.43	— 1.55	+ 4.82	— .94	+ 1.45	+ 1.78	— .12	— 1.89	— 2.78	+32.08
1928	— 4.37	— 4.68	—10.02	— 3.79	— 1.27	+ 1.39	+ 1.07	— 5.05	+ .19	+ 5.35	— 8.18	+ 9.01
1929	— 4.29	+ 2.61	— 1.11	— .33	— 5.57	— 3.52	+ 4.69	— 3.24	— 3.37	— 5.96	— .36	— 2.04
1930	— 8.81	— 5.82	+ .82	+ 8.33	+ 1.45	+ 4.34	+ .31	+ 7.00	+ 7.61	— 2.87	+ 8.72	— 9.79
Means	11.78	8.89	14.16	13.63	9.33	7.96	10.24	12.74	10.93	10.45	14.79	16.16

Annual—141.06

STATION OOKALA

Data, Rainfall Departures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— 3.86	— 4.66	+ 2.56	— 5.08	— .23	+ .16	+ .95	+ 3.99	....	+ 9.06	+ 4.10	— 3.04
1906....	— 8.69	— 6.68	— 6.62	+ .39	+ .17	— 1.73	+ .64	+ 2.31	— 3.69	— 3.92	— 4.09	+ 3.89
1907....	— 7.38	+ 3.27	+ 3.39	— .26	— 4.41	+ 3.24	+ 2.34	+18.90	+13.05	+ 1.80	— 4.57	— 8.53
1908....	— 5.72	+ 1.70	— 9.06	— 2.79	+ .12	— 1.46	+ 2.95	+ .33	+ 5.06	+ 3.04	— 1.93	+ 8.38
1909....	— 2.88	+ .42	+18.91	+ 2.16	— .61	— .51	+ 1.29	— 9.19	— 2.37	— 1.47	— 6.85	— 1.62
1910....	+ 6.46	— 1.98	— 1.75	— 6.01	+ 3.37	+ 4.70	— .34	+ 1.47	— 5.23	+ 2.26	+ .34	+13.04
1911....	+ 2.88	+14.82	— 3.19	+ 3.21	+ 2.97	+ 5.00	— .63	— 3.49	+ 6.88	— 3.16	— 1.61	— 4.25
1912....	— 7.88	+ 3.84	— 1.13	....	— 2.38	— 2.43	— 4.97	— 6.61	+ .29	+ 6.40	— 2.33	— 2.58
1913....	— .29	— 1.25	— 7.39	— 3.43	— .80	....	— 5.87	— 5.45	— 4.00	— 5.67	+10.75	— .65
1914....	+ 3.11	— 4.80	— 2.24	— 2.10	+17.13	+10.88	+21.77	+27.21	+13.10	+ 1.24	+ 6.26	— 1.13
1915....	— 2.84	+ 2.24	— 6.99	+ 3.66	— 3.88	+ .80	— 1.32	—10.32	— 1.34	+ 2.55	+11.59	— 4.95
1916....	+ 1.16	— 6.74	— 3.10	— .23	+15.79	....	+ 1.62	— 2.04	— 3.14	— 4.11	— 2.81	+13.93
1917....	— 6.47	— 2.28	— 5.46	— 9.59	— 4.06	— 1.36	— 5.97	—10.71	— 6.71	— 4.02	+ 2.73	— 5.46
1918....	+ 1.72	+17.64	+ 6.11	+36.40	+ 8.88	+ 5.73	+13.43	+ 2.87	— 4.55	— 1.99	+ 5.33	+13.27
1919....	— 1.96	— 3.38	+ 1.77	— 7.21	— 2.81	— 5.21	— 6.20	— 5.73	— 2.63	+ .37	—10.91	— 2.44
1920....	— 6.39	— 6.69	+ 6.58	— 8.26	— 8.01	— 4.46	— 3.86	— 5.62	— .08	+ 2.15	— 5.86	— 4.66
1921....	+28.87	— 5.26	— 1.61	— 5.29	— 4.95	— 4.75	+ 1.62	— 1.34	— 1.45	+ 2.33	+13.04	+ 2.12
1922....	+ 6.99	+ 3.80	+ 7.25	— 5.09	— 2.79	— 4.51	— 5.62	— 5.21	+ 1.14	— 2.10	+ 2.48	—10.95
1923....	+10.76	+ 2.29	+11.28	— 2.88	— .37	— .65	— .60	+ 1.80	+ 2.45	+ 3.45	— 5.79	+15.01
1924....	— 7.04	+ .26	— 4.68	+ 4.92	— 2.27	— 4.92	— .32	— 2.01	— 3.83	+ 7.67	— 2.05	— 8.80
1925....	+ .19	— 6.73	+12.27	— .03	— .40	+ .97	— 3.82	+ 5.17	— 2.27	— 5.27	— 3.73	—11.46
1926....	— 6.96	— 4.53	—12.29	— 1.80	— 3.57	+ .19	— 5.16	— 1.12	— 2.72	— 1.37	— .14	+ .06
1927....	+ 2.92	— 5.85	— 6.28	+ 3.60	— 4.54	— 2.56	+ 1.45	— 2.10	— .51	— 3.97	— 3.56	+ 2.64
1928....	— 3.47	— 2.84	— 6.74	— 6.74	— 1.69	— 3.76	+ 2.67	— 4.23	+ 3.79	+ .16	— 3.94	—.86
1929....	+ 5.18	+10.43	+ 5.59	— 2.28	— 3.36	— 3.64	— 3.95	— 6.36	— 5.64	— 3.67	+ 1.16	+ 7.63
1930....	+ 1.56	+ 2.95	+ 2.75	+14.79	+ 2.64	+10.09	— 1.99	+17.33	+ 4.51	— 1.66	+ 2.52	— 8.50
Means..	10.36	8.68	12.55	13.67	8.10	6.20	8.89	11.48	7.30	7.06	12.14	12.26

Annual—118.69

PAAUHAU STATION

Data—Rainfall Departures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— 1.89	— 3.66	— .35	— .83	+ .28	+ .15	+ .74	+ .74	+ 7.46	+ .97	— 2.29	— 1.68
1906....	— 6.03	— 5.15	— 5.85	— .59	— 1.78	— 1.56	+ 2.70	+ 3.36	— 2.26	— 1.91	— 2.08	+ 7.25
1907....	— 3.97	+ 3.62	+ 1.58	— 1.40	— 2.85	— .55	+ 4.51	+12.68	+ 3.95	+ 3.43	— 4.34	— 6.31
1908....	— 3.86	— 1.48	— 1.16	— 4.28	— 2.90	— 1.31	+ 1.34	+ .30	+ 1.46	+ .12	+ .53	+ 1.84
1909....	— 2.83	+ 1.62	+ 7.56	+ 6.14	— 1.05	— .81	— .16	— 4.84	— 1.85	— 1.13	— 5.49	— 1.06
1910....	+ 3.25	— .09	— 2.83	— 1.81	+ 2.39	+ 4.02	— .54	— .54	— 3.05	+ 2.47	— .53	+ 7.19
1911....	+ 3.59	+12.53	— .38	+ .29	+ 2.95	+ 3.50	— 1.40	— 1.37	+ 3.96	— .61	— 1.27	— 3.15
1912....	— 5.69	+ 2.22	— .19	+ 1.49	— 2.73	— 1.49	— 3.64	— 3.64	— .40	+ 1.09	— 1.30	— 4.36
1913....	— 4.93	— 3.07	— 6.07	— 1.97	— 1.80	— .03	— 2.90	— 2.14	— .50	— 2.83	+ 4.86	+ 7.45
1914....	+ 5.72	— 2.72	+ 4.34	— .93	+19.48	+ 3.59	+15.29	+20.16	+ 5.32	+ .99	+ 8.29	+ 1.17
1915....	— 4.01	+ 2.27	— 4.96	+ 3.43	— 2.27	+ 2.03	— 1.49	— 5.41	— .44	+ 2.16	+ 3.30	— 2.57
1916....	+ 5.11	— 5.16	— 1.19	— 1.61	+ 6.28	+ .61	— 2.15	— 2.55	— 1.88	— 1.65	— 4.59	+ 3.50
1917....	— 4.00	— 2.72	— 5.77	— 7.07	— 4.23	— 1.37	— 3.40	— 5.68	— 3.64	— 2.29	+ .07	— 4.36
1918....	— .15	+16.61	+ 5.04	+23.00	+12.76	+ 3.90	+ 3.56	— .61	— 3.04	— .66	— 1.33	+ 7.09
1919....	— 1.71	— 4.85	— .23	— 5.15	— 1.75	— 2.88	— 3.15	— 2.73	— 3.50	— 2.71	— 7.40	— 2.21
1920....	— 3.55	— 4.40	+ 5.34	— 5.63	— 4.72	— 2.69	— 3.08	— 2.34	— 1.16	+ .21	— 4.38	— 4.23
1921....	+ 8.95	— 5.27	— 1.06	— 3.44	— 4.16	— 2.76	+ .19	— 2.64	— 2.36	+ 1.99	+13.41	+ 5.96
1922....	+ 3.60	+ .82	+ 8.22	— 6.20	— 3.26	— 2.58	— 3.67	— 4.15	+ 4.65	— 1.89	— .10	— 7.89
1923....	+ 7.15	— .99	+ 4.98	— 1.12	— 1.73	— 1.06	— .66	+ 4.79	— .19	+ 5.38	— 4.47	+ 9.69
1924....	— 5.19	+ 2.41	— 4.53	+ 1.11	— 1.28	— 1.88	— 2.23	— 2.77	— 1.74	+ 2.66	— 1.18	— 6.96
1925....	— .64	— 4.99	+ 3.54	+ .01	— .55	+ .07	— 2.02	+ 3.07	— .80	— 2.34	— 4.06	— 7.49
1926....	— 4.86	— 2.91	— 4.92	— 2.15	— 2.97	+ 1.31	— 2.20	— .15	— .87	+ 2.26	— 1.88	— 6.24
1927....	+ 5.45	— 3.11	— 4.83	+ 3.58	— 3.57	— 1.61	+ 3.23	— 2.17	+ .08	— 1.37	+ .79	— .79
1928....	— 1.76	— 2.42	— 2.99	— 6.15	+ .22	— .05	+ 2.54	— 2.24	+ 1.42	— 1.74	— 2.17	+ .69
1929....	+ 6.86	+11.33	+ 4.73	+ .46	— .72	— 1.37	— 1.96	— .56	— 3.22	— 2.23	+ 5.19	+12.55
1930....	+ 5.45	— .51	+ 1.91	+10.78	+ .08	+ 4.83	— .31	+ 1.50	+ 2.66	— .29	+12.33	— 5.00
Means..	6.99	6.00	7.87	8.19	4.72	2.95	4.33	5.74	3.73	3.00	8.10	8.06

Annual—69.68

PAAUILO STATION

Data—Rainfall Departures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— 1.43	— 4.54	+ .23	— 4.10	— .99	— .31	— .80	+ 1.10	+ 7.10	— 1.76	— .70	— 3.99
1906....	— 8.19	— 5.71	— 7.34	— .68	— 1.64	— 1.91	+ 2.28	+ 2.36	— 3.08	— 2.57	— 4.08	+ 4.79
1907....	— 6.05	+ 2.39	— 2.80	— 2.44	— 3.21	— .39	+ 3.25	+18.01	+ 8.70	+ 3.04	— 6.35	— 8.15
1908....	— 4.25	— 5.76	— 7.67	— 2.64	— 2.82	— 2.29	+ 1.11	— .93	+ 1.13	+ 2.55	— .54	+ 5.74
1909....	— 3.02	+ .40	+13.06	+ 7.37	— 2.13	— 1.38	— .98	— 7.89	— 3.49	— 1.64	— 7.48	— 4.52
1910....	+ 5.65	— 1.07	— 1.27	— 3.52	+ 3.57	+ 5.12	— 1.25	+ 1.32	— 3.55	+ 1.88	+ .57	+ 4.59
1911....	+ 1.13	+15.90	— 1.80	— .11	+ 2.57	+ 4.52	— 1.64	— 1.81	+ 4.19	— 1.38	— 1.57	— 5.09
1912....	— 6.67	+ 2.30	+ .11	+ 2.60	— 2.93	— 2.81	— 4.93	— 5.81	+ .62	+ 4.19	— .19	— 5.23
1913....	— 4.07	— 2.56	— 6.58	— 2.32	— .89	+ .47	— 4.24	— 4.20	— 2.54	— 3.32	+ 5.72	+39.10
1914....	+ 7.23	— 4.70	— 1.32	— 2.12	+21.91	+ 7.04	+20.50	+25.04	+ 8.59	+ 2.49	+ 6.10	— 3.86
1915....	— 4.94	+ .36	— 7.23	— .74	— 3.37	+ .85	— .43	— 7.79	— .84	+ 3.37	+ 6.89	— 5.16
1916....	+ .18	— 5.92	— 4.18	+ 2.55	+14.79	+ .02	— 1.45	— 2.68	— 2.85	— .89	— 5.25	+ 6.60
1917....	— 4.18	— 3.21	— 6.09	— 9.05	— 3.48	— 1.24	— 4.30	— 7.85	— 5.35	— 2.00	+ 3.01	— 7.31
1918....	— 1.73	+17.05	+ 2.96	+32.36	+14.05	+ 4.56	+ 7.43	+ .47	— 3.95	— .68	+ 2.03	+11.94
1919....	— 3.68	— 4.32	— .58	— 7.56	— 3.64	— 4.11	— 9.42	— 5.60	— 4.15	— 3.10	— 9.79	— 4.61
1920....	— 5.34	— 5.34	+ 6.59	— 7.27	— 6.20	— 3.93	— 4.09	— 4.27	— 1.96	— .03	— 4.96	— 6.95
1921....	+17.62	— 5.92	— .90	— 5.22	— 4.93	— 3.91	— .14	— 4.06	— 2.78	+ 2.75	+13.64	+ 3.42
1922....	+ 6.04	+ 2.31	+12.27	— 7.19	— 3.50	— 3.12	— 4.84	— 4.74	+ 2.44	— 2.31	+ .47	—12.41
1923....	+12.82	— 1.39	+ 6.26	— 3.18	— 2.28	— 1.67	— 1.70	+ 7.05	+ .98	+ 4.69	— 6.88	+10.77
1924....	— 7.06	+ 2.91	— 5.01	+ 2.67	— 4.33	— 3.76	— 2.14	— 4.18	— 3.40	+ 2.00	— 1.54	—11.75
1925....	— .70	— 5.17	+ 7.50	— 4.77	— 2.31	— 1.21	— 3.82	+ 1.98	— 1.27	— 3.45	— 5.94	—11.97
1926....	— 6.96	— 3.76	— 8.42	— 5.94	— 4.59	+ .22	— 4.39	— 1.39	— 2.59	— 1.36	— 1.47	—10.44
1927....	+ 2.83	— 4.82	— 7.49	+ .87	— 5.09	— 2.44	+ 3.61	— 1.80	+ .21	— 1.37	+ 2.77	— .44
1928....	— .59	— .87	— 1.36	— 6.29	+ 1.59	+ 1.43	+ 3.92	— 3.30	+ 4.80	— 1.69	— 3.64	+ 3.58
1929....	+10.28	+18.02	+ 8.23	+ 8.12	— 2.11	— 1.98	— 2.26	— .19	— 5.05	— 1.96	+11.45	+18.74
1930....	+ 5.05	+ 3.35	+ 7.21	+18.54	+ 2.01	+12.17	+ 6.31	+10.09	+ 8.06	— .96	+ 7.63	— 7.32
Means..	8.95	7.14	10.45	11.33	6.23	4.31	6.10	8.06	5.45	4.03	10.29	12.55
Annual—94.89												

PAHALA STATION

Data—Rainfall Departures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— 5.01	— 2.96	— 4.19	— 2.61	+ .26	— .26	+ .48	— .75	— .34	— 1.43	+ 4.50	— 5.22
1906....	— 4.22	— 2.38	— 4.59	— 3.15	+ 1.16	— .86	— .91	+ 5.25	— 2.14	— 2.88	+ 9.27	+ 1.20
1907....	+ 6.48	+ .51	— 2.31	— 2.53	— .55	— .57	— .35	+ 9.66	+ 5.50	+ 4.73	— 4.18	— 5.67
1908....	— 4.66	+ 2.63	+ 3.89	— 1.49	— 2.26	— 1.07	— 1.37	— 2.82	— 1.04	— 2.54	— 3.72	— 5.32
1909....	— 5.50	+ .21	— 1.04	— .54	— .80	— .82	— .73	— 3.00	+ 1.10	+ 3.02	— 4.42	+ 6.57
1910....	— .80	— .12	— 5.27	— 3.25	— 1.68	— .44	— .81	+ 2.86	+ .52	— 2.92	— 2.47	— 3.62
1911....	— 3.18	+ 5.01	+ 6.05	+ 1.80	+ .41	— .97	— .59	— .87	— .24	+ .02	— 4.76	— 2.56
1912....	— 5.41	— .11	— 4.72	— 2.93	— 1.84	— .32	— .14	— 1.08	— 1.94	— 1.89	— 5.05	— 4.59
1913....	— .97	— .52	— 5.18	— 3.44	+ 5.41	+ 2.03	— 1.16	— 1.12	— 1.69	— .99	+ 6.17	— 4.02
1914....	— 1.40	— 2.70	— 1.85	— 2.15	+ .66	+ 1.52	+ 6.45	+ 2.98	+ 1.41	— 3.11	— .55	+ 3.72
1915....	— 5.71	— 2.47	— 3.77	+ 2.49	— 1.43	+ 1.53	+ 2.12	— 1.10	— .34	+ 3.29	+27.28	+ 7.64
1916....	+12.34	— 3.02	+ 8.24	— .31	+ 1.29	— 1.04	— 1.35	— 2.18	— .85	+ 1.99	— 3.70	+12.79
1917....	+ 4.75	+ 3.04	+13.18	+ 3.79	+ 6.66	— .49	— .83	— 2.65	— 1.71	— .17	— 4.58	+ 2.69
1918....	+11.24	+17.62	+ 5.24	+ 5.54	+ 1.11	+ 1.28	+ 2.56	— .51	— .99	— 2.61	+ 5.58	— 5.39
1919....	— 5.14	— 4.08	— 1.99	— 3.27	— .57	— .25	+ .04	+ 1.45	— .18	+ 1.08	— .94	— 2.64
1920....	+ 2.25	— 2.57	+ 1.15	— 1.84	+ 1.85	+ .12	— .61	— 1.27	— 1.81	+ .22	— 4.18	+ 5.60
1921....	+10.79	— 1.45	— 2.69	— 2.49	+ 1.37	— .97	— .78	— 1.83	— 1.86	+ 3.48	— 3.83	— 3.35
1922....	+ .91	+ 1.83	— 2.21	— 1.77	— 1.86	— .23	— 1.08	— 2.19	— .20	— 2.03	— 2.32	— 2.77
1923....	+13.78	+ 9.04	+ 5.49	+13.75	— 1.17	— .65	— .80	— .17	+ 3.32	— 3.69	— 4.09	+ 4.26
1924....	— 5.51	— 3.41	+ 5.15	+12.23	+ .85	+ 1.16	— .25	— 2.12	— .65	+ 3.87	+ 1.33	— 1.58
1925....	— .95	— 2.11	+ .20	— 3.16	— .98	+ .04	+ .80	— 1.68	— 1.60	+ .09	— 3.81	— 5.41
1926....	— 2.49	— 3.67	— 5.09	— 2.00	— .76	+ 1.28	— .68	+ 5.05	— 1.70	+ 3.05	— 3.98	+ 2.32
1927....	— 4.40	— 3.84	+ 2.78	+ 3.71	— 2.10	— .61	— 1.12	— 1.67	+ 6.20	+ 2.68	— 4.35	+34.71
1928....	— 5.50	— 3.30	— 4.90	— 2.19	— .07	+ 1.88	+ .31	— 2.50	— .59	+ .10	— 3.74	— 4.22
1929....	+ .51	+ 1.69	— 3.67	— 2.16	— 1.01	— .60	+ 1.24	— 1.98	— .74	+ .30	+11.40	+ .39
1930....	— 2.17	— 2.89	+ 3.12	— 2.13	— 1.74	— .67	— .49	+ 4.13	+ 2.51	+ 2.11	— .99	— 5.64
Means..	5.82	4.10	5.78	3.54	2.30	1.07	1.37	3.00	2.40	3.86	5.21	5.81

Annual—44.26

PAPAIKOU STATION

Data—Average Monthly Precipitation

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	—14.04	— 2.64	—10.77	— 8.58	— 2.41	— .12	— 1.82	+ .52	+ 9.57	— .56	+17.39	— 3.08
1906....	—10.26	— 8.56	—16.21	— 6.42	— 1.58	— 3.37	+ 1.00	+ 9.00	— 5.23	— 6.23	— .15	+ .47
1907....	— 8.49	+ 6.56	— 1.64	—10.49	— 4.42	+ 3.90	— 3.04	+27.90	+23.01	+ 6.39	— 5.36	—12.94
1908....	— 4.76	+15.08	—11.88	+ 6.14	+ .72	— .84	— 1.70	— .79	+ 7.01	+ 3.95	— 9.32	— .77
1909....	— 7.01	+ 1.45	+19.17	— 5.35	+ 3.71	— .22	+ 5.31	— 9.18	— 3.67	— .96	—13.95	+ 8.39
1910....	+10.25	— 6.63	+ 2.02	— 3.00	+ 5.11	+ 4.13	+ 1.02	+ 2.25	— 7.35	— 3.11	— 3.09	— .97
1911....	+ 5.47	+ 6.93	— 6.12	+ 3.68	+ 6.88	+ 4.38	+ .19	— 5.56	+ 6.59	— 2.35	+ .97	— .95
1912....	—15.65	+ 7.33	— 2.88	+ 8.54	— 3.11	+ .99	— 5.38	— 6.63	— 6.62	+10.61	— 1.37	+ 2.05
1913....	+20.10	— 2.02	— 8.88	— 1.77	— 2.80	+ .87	— 5.62	— 6.45	— 8.25	— 8.46	+ 9.28	— 5.48
1914....	— 5.65	— 6.82	— 7.01	— 6.11	+20.08	+18.63	+18.83	+32.07	+24.20	— 1.40	+ 2.03	— 3.40
1915....	—11.07	+ 3.33	—15.32	+14.75	— 7.94	+ 2.55	— .09	—10.03	— 6.56	+ 8.75	+33.39	+ 3.04
1916....	— 2.57	— 8.67	— 3.61	— .93	+18.50	+ 4.96	— 1.19	+ 7.40	+ 1.47	+ .72	+ 6.50	+26.28
1917....	+ 7.67	— 6.71	+ 9.72	+ 1.13	— 4.23	— .76	— 3.74	—12.49	—10.28	— 6.84	+ 4.68	—10.23
1918....	+10.51	+29.85	+20.46	+18.85	+11.86	+ 1.96	+21.18	+ 1.43	— 5.12	— .98	+ 5.54	+ 9.73
1919....	— 9.71	— 2.99	— 2.07	—10.79	— 4.84	— 3.89	— 3.11	— 2.40	— 1.66	— .43	— 6.23	—13.16
1920....	—10.82	— 5.06	+17.23	— 8.79	—10.34	— 5.57	— 2.47	— 7.84	+ .19	+ 7.09	— 7.11	— 4.07
1921....	+47.26	— 5.36	—13.68	— 3.17	— 8.09	— 7.44	— 3.15	— 5.35	— 6.81	+ 5.29	+16.52	+12.12
1922....	+15.34	+18.25	+50.31	+ 1.54	— 1.13	— 6.97	— 5.81	— 4.63	+ 6.39	— 1.17	+ 8.57	—15.10
1923....	+42.52	— 2.52	+16.44	+17.00	+ 2.30	+ 3.84	+ 1.77	+ .60	+10.36	+ 4.94	— 8.48	+22.28
1924....	—13.15	— 2.17	—10.88	+17.76	— 2.48	— 6.30	+ 4.66	+ 1.12	— 4.13	+13.47	— 7.97	—14.44
1925....	— 2.50	— 8.76	+15.28	— 2.06	+ 2.73	+ 1.38	— 9.28	+ 1.10	— 2.23	— 7.76	— 7.36	—17.79
1926....	—13.06	— 4.69	—17.71	—15.10	— 4.69	— 6.51	— 8.25	+ .97	— 4.85	— 5.78	—13.60	— 3.15
1927....	— 3.71	— 7.11	— 1.44	— 6.27	— 2.08	— 4.60	+ 1.07	— 2.53	— 2.33	— 4.63	— 3.72	+30.06
1928....	— 8.16	— 5.77	—14.15	— 9.93	— 2.29	— 3.34	+ 2.77	— 7.22	— 3.42	+ .53	—11.36	+ 7.88
1929....	— 7.50	+ 4.50	+ .87	— 3.88	— 8.61	— 7.69	+ .78	— 7.98	—10.61	— 8.20	— 6.65	— 4.52
Means..	16.62	11.25	19.42	17.15	12.45	10.61	13.45	16.60	14.82	12.90	18.60	19.00

Annual—182.87

STATION PEPEEKEO

Data—Rainfall Departures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1905....	— 8.01	— 2.19	— 4.48	— 4.91	— .24	— .63	+ .5	+ 1.33	+ 2.96	— .13	+11.84	— 2.96
1906....	— 7.91	— 6.30	— 7.66	— 5.65	— .73	— .73	— .29	+ 6.13	— 3.20	— 5.78	+ 3.08	— .30
1907....	— 6.51	+ 4.74	— .25	— 5.58	— 3.24	+ 1.67	+ .46	+17.01	+13.43	+ 5.08	— 2.60	— 8.79
1908....	— 5.35	+14.84	— 4.97	+ 2.30	— 2.96	— 2.08	— 3.43	— 2.93	+ 1.41	+ .64	— 3.13	+ .08
1909....	— 5.36	— 1.92	+19.11	+ .57	+ 2.27	— 1.75	+ 2.77	— 5.46	— 2.26	— 3.72	— 9.77	+ 5.24
1910....	+ 7.34	— 3.20	+ 2.25	— 5.36	+ .70	+ 3.71	— 1.63	+ 2.29	— 6.88	— 1.79	— 2.34	+ 3.18
1911....	+ 2.90	+ 4.45	+ .15	+ .15	+ 7.76	+ 3.32	— .95	— 3.97	+ 3.57	— .99	— .67	— 4.23
1912....	—11.49	+ 2.01	+ .9	+ 3.98	— 1.60	+ 1.42	— 4.20	— 4.13	— 5.77	+ 6.30	+ .23	+ 3.34
1913....	+19.42	— 2.37	— 5.52	— 2.24	— .85	+ .47	— 3.30	— 4.73	— 6.04	— 4.15	+ 7.08	— 4.39
1914....	— 3.96	— 3.18	— 2.27	— 3.72	+13.69	+ 8.53	+ 9.72	+18.45	+16.82	— 1.42	+ 2.79	— 3.47
1915....	— 8.46	— .87	— 8.92	+ 9.26	— 5.33	+ 3.32	— .35	— 6.09	— 4.07	+ 3.69	+21.94	+ 1.17
1916....	— 1.38	— 6.89	— 1.65	+ .24	+ 9.71	+ 1.42	— 1.73	+ 1.40	+ 1.29	+ 2.46	+ .14	+14.24
1917....	+ 1.60	— 4.06	+ 8.80	+ .76	— .10	+ .44	— 3.30	— 7.24	— 7.37	— 6.75	+ 2.24	— 6.23
1918....	+ 8.36	+18.70	+12.38	+11.07	+ .47	+ 3.05	+11.64	— 1.73	— 5.18	— 1.27	— 2.60	+ 1.01
1919....	— 7.81	— 1.84	— 1.20	— 5.99	— 3.63	— 2.18	— 3.03	— 2.15	— 4.46	— .64	— 7.28	—10.27
1920....	— 6.96	— 3.92	+12.11	— 5.80	— 7.37	— 3.90	— 2.55	— 4.77	+ 1.03	+12.00	— 5.74	— 2.16
1921....	+20.84	— 2.98	— 5.90	— 1.67	— 4.45	— 3.14	— .66	— 2.02	— 5.44	+ 2.97	+ 8.00	+ 2.69
1922....	+10.93	+ 9.58	+23.21	+ .79	— 1.21	— 5.08	— 2.88	— 4.20	+ 7.02	— 2.68	+ 5.82	— 9.93
1923....	+30.92	— .53	+12.05	+10.65	— .16	+ .69	+ 3.00	+ .54	+ 6.62	+ 4.79	— 6.79	+ 13.20
1924....	— 8.24	— 1.05	— 3.02	+ 6.37	— 1.65	— 4.11	+ 2.87	— .94	— 3.07	+ 7.30	— 6.47	—10.23
1925....	— .96	— 5.86	+14.04	— 2.76	+ 2.81	+ .49	— 4.89	+ 1.10	+ 2.71	— 4.54	— 2.10	—12.69
1926....	— 8.16	— 2.13	— 9.45	— 8.18	— 2.69	— 4.66	— 4.35	+ 3.91	— 2.16	— 3.74	— 7.66	— .75
1927....	+ .55	— 5.11	+ 7.59	— .92	+ 2.10	— 2.06	+ 2.41	— .46	— .28	— .98	— .53	+28.50
1928....	— 6.13	— 3.06	— 7.85	— 6.90	+ 1.50	— 1.70	+ 2.21	— 3.47	+ 2.00	+ 2.34	— 6.92	+ 8.22
1929....	— .94	+ 5.68	— .55	— 1.31	— 4.85	— 3.97	+ 5.16	— 3.23	— 4.41	— 6.22	— 1.86	+ 4.81
1930....	— 5.19	— 2.48	+ 2.38	+14.91	+ .14	+ 7.49	— 2.85	+ 5.36	+ 1.78	— 2.79	+ 3.22	— 9.26
Means..	12.44	8.07	11.66	11.91	8.59	7.39	9.30	11.30	11.33	9.62	12.80	13.83

Annual—128.24

STATION HANA

Data—Rainfall Departures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1907....	....	....	....	....	— 1.97	+ 3.92	+ .20	+12.42	+ 5.88	+ 2.43	+ 4.87	— 7.20
1908....	— 6.24	+ 4.31	— 2.54	— 4.21	+ 3.65	+ 1.03	+ .54	+ .86	— 1.82	— 2.77	+ 2.71	— 5.23
1909....	— 6.57	+ 1.05	+16.60	+ 5.15	— .45	+ 2.25	+ .79	— 2.91	— 2.05	— .89	— 4.60	+ 2.46
1910....	+ 4.65	— 1.03	— 2.76	— 5.03	+ .03	+ 1.37	— .95	+ 8.99	— 1.33	— 1.10	— 3.46	+22.35
1911....	+ 1.28	+ 4.24	— 1.49	— 3.92	+ 1.93	+ .41	— 1.73	+ .60	+ 5.34	— 1.88	— 3.55	— 5.42
1912....	— 7.72	— 1.34	— 3.36	— 3.82	— .58	— 1.58	— 1.65	— 2.45	— 3.40	+ .83	— 3.20	— .60
1913....	— 1.76	— 1.96	— 5.62	— 4.43	+ 2.72	+ .37	— 1.18	+ .31	— 3.31	— .10	+ 1.67	— 2.62
1914....	— 2.67	— 3.65	+12.88	+ 5.49	+ 9.51	+ 1.45	— 1.03	+ .50	+21.60	— 1.20	— .60	+ 8.38
1915....	— 6.80	+ 4.11	— 6.76	+26.42	— 2.55	— .12	+ .64	— 1.72	— 2.62	+ .84	+13.38	+ 3.23
1916....	+16.11	— 2.38	+ 5.73	+ 1.38	— 1.22	+ 1.33	+ .84	....	....	+ 1.11	— .78	+ 1.50
1917....	— 4.01	— .42	— 3.89	— .55	— .69	— 2.28	— .35	— 1.68	— 3.15	+ 2.63	— 2.38	— 4.60
1918....	+ 1.58	+ 3.14	+ 5.73	+18.18	+ 1.69	— .69	+ 1.20	+ 1.73	— 1.95	— 1.56	— 1.33	— 1.01
1919....	— 5.32	— 2.89	— 4.56	— 6.61	— .63	— .40	+ .90	— .44	— .52	— .06	— 3.98	— 7.50
1920....	— 3.61	— 3.23	+12.74	— 7.95	— 3.05	— 1.30	— .63	— 1.13	— 1.96	+ 1.03	— 1.24	+ .59
1921....	+ 7.19	— 3.92	— 2.00	— 4.56	— .79	— 1.21	+ 2.00	— 1.66	— 1.13	— 1.83	+ 3.19	+ .86
1922....	+19.09	— .26	— 2.11	— 7.42	— 1.78	— .91	— 2.56	— 2.05	— 2.03	+ 2.16	+ 2.22	— 6.67
1923....	+ 9.08	+ 1.37	— .13	+ 3.59	— 2.01	— 1.15	— 1.08	— 2.04	+ .83	+ 2.52	— 1.06	+ 6.82
1924....	— 6.75	— .76	— 4.17	+ 6.63	+ .37	— .21	+ 1.56	— 2.06	+ 2.74	+ 1.49	— 5.06	— 3.63
1925....	— 4.25	— 1.05	+ .35	— 5.12	— .95	— .01	— .64	— .63	— .57	— .54	— .17	— 2.73
1926....	— 5.78	— 2.76	— 6.14	— 5.79	— 2.50	+ 1.37	— .44	— .03	— 1.10	— .48	— 1.94	— 5.16
1927....	— 1.22	— 1.90	— 2.87	+ 7.44	— .12	— 1.12	— .72	+ .79	+ .62	— .79	— .36	+12.21
1928....	— 4.00	— .54	— 4.72	+ .44	— .82	— .62	+ 2.06	+ .23	— 1.64	— 1.81	— 2.81	— 1.32
1929....	— 1.02	+ 8.45	— 3.90	— 7.19	+ .18	— 1.36	+ 1.08	+ .59	— 1.70	— .75	+ 6.74	+ 5.55
1930....	+ 8.69	+ 1.40	+ 3.00	+ 2.22	+ .02	— .59	+ 1.14	— 2.76	— .90	+ .65	+ 7.10	— 4.89
Means..	8.56	5.42	7.54	9.42	4.57	3.77	4.31	5.36	5.22	4.90	6.67	9.47

Annual—75.21

TABLE J

DATA—EXTREMES OF TOTAL MONTHLY RAINFALL

HAWAII

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Hakalau	39.97	24.71	43.87	27.45	30.16	18.86	17.88	37.21	37.31	30.05	46.49	43.75
	2.29	1.23	1.54	3.61	0.23	1.77	3.69	2.91	2.56	4.00	6.18	2.91
Hilo	41.60	29.43	66.96	22.84	20.48	25.47	23.45	37.77	26.28	25.08	31.40	51.88
	0.99	1.92	1.75	2.00	1.31	2.32	4.77	2.42	2.50	2.64	4.09	1.32
Honokaa	19.00	24.32	15.99	17.88	18.66	8.32	19.45	17.85	12.06	8.15	24.79	19.47
	1.21	0.57	1.41	1.36	0.05	0.19	0.45	0.15	0.36	0.20	1.56	0.22
Kohala	15.10	10.68	11.40	18.78	12.40	10.85	12.62	18.43	8.63	5.73	13.92	14.96
	0.86	0.49	1.20	1.81	0.68	0.68	1.29	0.69	0.38	0.97	1.13	0.76
Naalehu	16.42	9.78	13.76	13.00	5.88	4.78	4.90	11.64	11.49	8.10	14.79	25.71
	0.40	0.12	0.20	0.45	0.40	0.24	0.22	0.11	0.12	1.34	0.41	0.40
Niulii	18.06	9.79	11.92	18.80	14.56	11.56	14.78	19.53	9.20	6.14	14.00	15.11
	1.01	0.40	0.96	1.97	0.48	0.76	1.82	0.87	0.33	0.91	1.11	0.44
Olaa	37.86	31.27	44.56	28.04	21.98	25.75	22.46	34.18	22.97	19.87	37.08	48.24
	1.06	1.54	2.31	1.94	1.80	2.04	4.21	3.77	3.16	3.46	3.18	3.13
Ookala	39.23	19.11	31.46	50.01	25.23	17.08	30.66	38.69	20.40	16.12	25.18	27.27
	1.67	1.94	0.26	4.08	0.09	0.98	2.69	0.77	0.59	2.95	1.23	0.80
Paauhau	15.94	22.61	16.09	31.19	24.20	7.78	19.62	25.90	9.05	8.38	20.43	20.61
	0.96	0.73	1.80	1.12	0.00	0.07	0.66	0.06	0.09	0.17	0.70	0.17
Paauilo	25.57	25.16	23.51	43.69	28.14	16.48	26.60	33.10	14.15	8.72	23.93	31.29
	0.76	1.22	2.03	2.28	0.03	0.20	1.17	0.21	0.10	0.58	0.50	0.14
Pahala	19.60	21.72	18.96	17.29	8.96	3.10	7.82	12.66	8.60	8.59	32.49	40.52
	0.11	0.02	0.51	0.10	0.04	0.00	0.00	0.00	0.26	0.17	0.16	0.14
Papaikou	63.88	41.10	69.73	36.00	32.53	29.24	34.63	48.67	39.02	23.51	51.99	49.06
	0.97	2.49	1.71	2.05	2.11	2.92	4.17	4.11	4.21	4.44	4.65	1.21
Pepeekeo	33.28	26.77	34.87	26.82	22.28	15.92	20.94	29.75	28.15	21.62	34.74	42.33
	0.95	1.18	2.21	3.73	1.22	2.31	4.41	4.06	3.96	2.87	3.03	1.14
MAUI												
Hana	27.65	13.87	24.14	35.84	14.08	7.69	6.37	17.78	26.82	7.53	20.05	31.82
	0.84	1.50	0.78	1.47	1.52	1.10	1.75	2.45	1.82	2.13	1.61	1.97

TABLE K

STATION PEPEEKEO

DATA—SEASONAL RAINFALL

Year	Winter	Spring	Summer	Fall
1905................	17.49	22.11	36.27	45.00
06................	10.30	20.78	34.57	33.25
07................	30.15	20.74	62.83	35.30
08................	36.69	25.15	26.98	33.84
09................	44.00	28.98	26.98	28.00
10................	38.56	26.94	25.71	35.39
11................	39.67	39.12	30.58	30.36
12................	22.78	31.69	17.83	46.12
13................	43.70	25.27	17.86	34.79
14................	22.76	46.28	76.92	34.15
15................	13.92	35.14	21.42	63.05
16................	22.25	39.26	32.89	53.09
17................	38.51	28.99	14.02	25.51
18................	71.61	42.48	36.66	33.39
19................	21.32	16.09	22.29	18.06
20................	33.40	10.82	25.64	40.35
21................	44.13	18.63	23.81	49.91
22................	75.89	22.39	31.87	29.46
23................	74.61	39.07	42.09	47.45
24................	19.86	28.50	30.79	26.85
25................	39.39	28.43	30.85	16.92
26................	12.43	12.36	29.33	24.10
27................	35.20	27.01	33.60	63.24
28................	15.13	20.79	32.67	39.89
29................	36.36	17.76	29.45	32.98
30................	26.88	50.43	36.22	27.42
Means............	32.17	27.89	31.93	36.25
Extremes	75.89	50.43	76.92	63.24
	12.43	10.82	14.02	16.92

Sunshine Data

While there are some temperature and rainfall data, there are practically no data on sunshine. So far as we know, only three plantations have been keeping sunshine data for the last few years. The data from two plantations together with the complete data of the U. S. Weather Bureau at Honolulu are given in Table L.

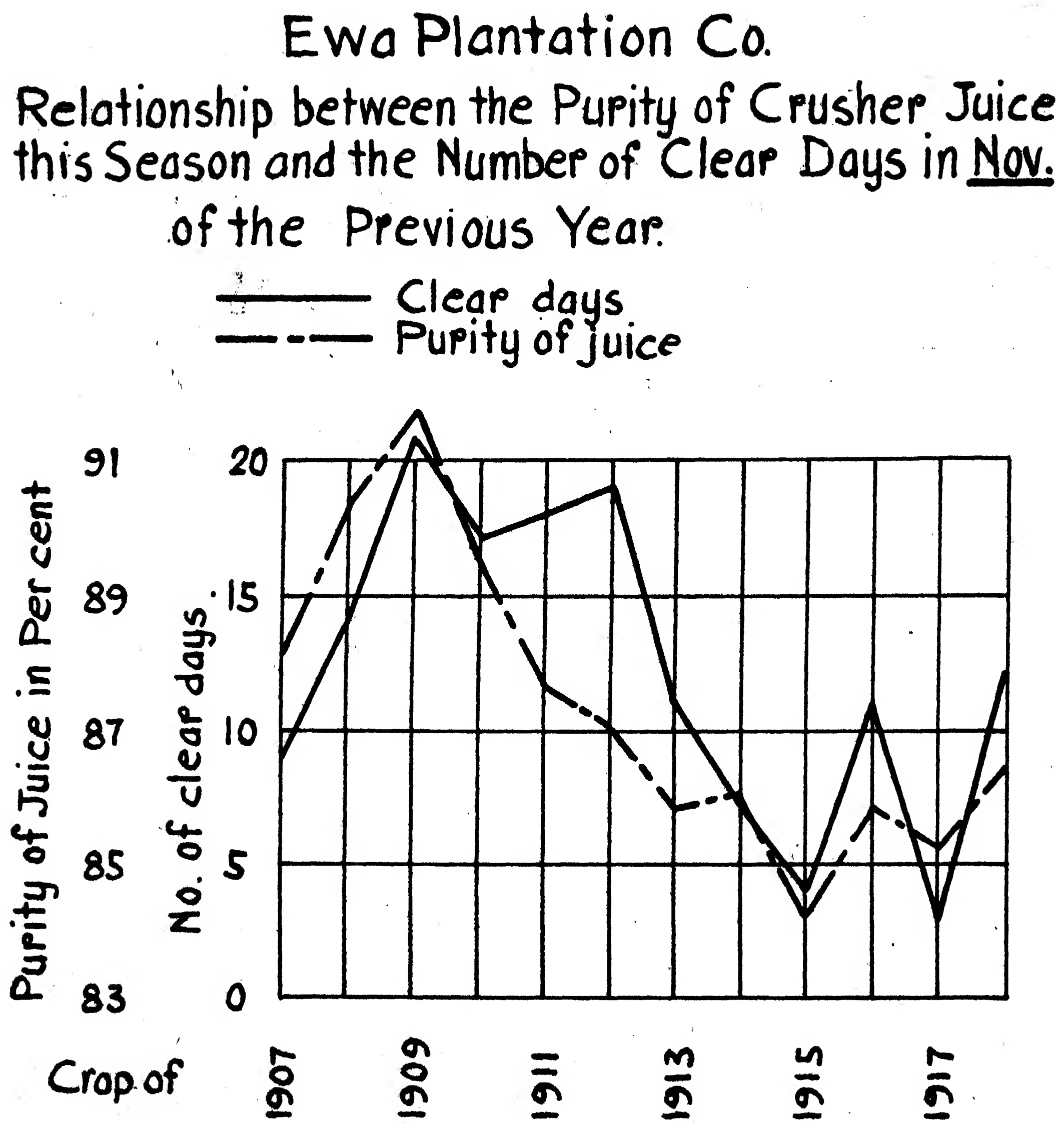


Fig. 9

Seeing that sugar cane is mainly a storehouse of carbohydrates, the relation of hours of sunshine to sucrose formation must indeed be great. In fact a study of the relation of juice quality to the number of bright, clear days at Ewa indicate quite definitely that even in these islands the amount of sunshine is far from being overabundant—that the variations in the quality of juice may be appreciably influ-

enced by the variation in the amount of sunlight from year to year (Fig. 9). We believe that the amount of sunshine plays a role of great importance in the growth and development of the sugar cane plant, and bright, clear days, and a great amount of sunshine are essential to high production of cane and sugar.

Some plantations keep monthly records of the number of clear, and cloudy days. These records, even though very incomplete, are of great help in studying cane production and juice quality. In places where the observer has been the same person over a number of years, the records will be of great value in a comparative study of the amount of sunshine from year to year. Where observers have changed, personal errors may have crept in.

TABLE I.

STATION HONOLULU

DATA—ACTUAL HOURS OF SUNSHINE

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1904									281	203	165	158	
05	184	229	222	243	322	304	288	273	261	268	224	226	3044
06	246	256	256	300	260	276	278	266	229	226	185	136	2914
07	127	194	120	115	243	262	248	213	204	203	158	268	2354
08	263	250	220	266	292	272	279	295	245	241	244	229	3096
09	212	192	178	204	260	230	202	269	248	223	246	156	2620
10	154	198	241	194	247	259	289	270	204	237	209	193	2696
11	147	191	231	205	264	256	234	244	195	229	219	185	2601
12	224	176	156	227	240	216	215	241	210	266	193	187	2551
13	240	242	283	292	314	293	356	346	338	315	225	271	3515
14	245	277	269	310	332	341	354	334	290	334	304	294	3685
15	316	208	316	283	308	285	279	255	236	205	100	105	2896
16	84	155	212	255	249	215	255	235	206	194	143	126	2329
17	164	158	127	188	208	238	262	270	244	210	182	174	2425
18	169	168	219	162	254	264	267	279	280	264	226	241	2793
19	257	243	272	215	284	306	334	328	296	279	252	227	3293
20	235	255	207	233	184	269	278	306	274	267	197	211	2917
21	126	233	224	239	214	231	233	268	228	240	179	173	2588
22	149	149	235	237	236	191	245	236	216	227	214	244	2579
23	122	176	170	221	261	249	217	209	215	227	206	127	2399
24	255	186	226	170	247	214	249	280	238	199	174	211	2648
25	230	201	217	160	180	236	278	320	261	237	188	181	2690
26	207	206	217	238	254	244	287	282	276	239	229	175	2855
27	212	212	160	198	238	284	248	288	242	238	174	142	2635
28	214	227	229	236	236	270	272	282	287	265	184	241	2942
Means 1905-28	199	211	216	224	256	258	268	274	245	246	203	195	2795
1929	240	205	253	245	251	265	297	292	272	267	177	182	2946
1930	212	238	223	248	301	242	288	254	255	272	247	241	3021
1931	242	229	238	251	241								

Annual total hours possible=4436.
" " " obtained=2795 or 63%.

STATION OAHU SUGAR COMPANY

DATA—HOURS OF SUNSHINE

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Total Possible	342	320	373	379	407	402	411	398	367	361	334	338
1926							284	294	285	264	264	240
27	242	224	199	233	232	251	236	261	233	239	154	110
28	167	194	234	252	231	332	351	347	311	267	208	264
29	256	186	232	259	228	279	274	272	258	267	192	219
30	225	215	214	232	317	258	297	230	226	271	226	247
31	208	209	214	263								

HONOKAA MILL STATION

DATA—HOURS OF SUNSHINE

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1920	131	219	215	234	310	299	283	296	287	288	277	190
21	124	200	136	146	258	267	282	157	130	98	74	88
22	72	58	91	114	284	250	249	229	176	199	130	149
23	88	115	109	121	190	183	188	250	250	221	146	106
24	171	118	199	176	207	262	220	230	230	177	164	189
25	148	153	162	126	140	174	239	185	176	199	144	302
26	298	251	292	193	290	295	296	250	258	241	195	174
27	177	221	193	172	268	284	288	219	253	232	185	143
28	180	190	225	209	208	308	272	273	217	216	158	148
29	116	139	200	209	227	243	290	259	265	232	149	81
30	148	161	152	89	214	196	181	177	188	195	139	144
31	166	147	159	153								
Means												
1920-30	150	166	179	163	236	251	249	230	221	209	160	156

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
JUNE 17 TO SEPTEMBER 14, 1931

Date	Per Pound	Per Ton	Remarks
June 17, 1931......	3.33¢	$66.60	Cubas.
" 18...........	3.35	67.00	Cubas, Porto Ricos.
" 23...........	3.36	67.20	Cubas.
" 24...........	3.39	67.80	Porto Ricos, 3.38; Philippines, Cubas, 3.40.
" 25...........	3.40	68.00	Cubas, Philippines.
" 30...........	3.425	68.50	Cubas, 3.40, 3.42, 3.43, 3.45; Porto Ricos, 3.45.
July 1...........	3.47	69.40	Cubas, 3.46, 3.47, 3.48.
" 2...........	3.45	69.00	Cubas.
" 3...........	3.445	68.90	Cubas, 3.45; Philippines, 3.44.
" 6...........	3.42	68.40	Philippines.
" 8...........	3.44	68.80	Cubas.
" 10...........	3.45	69.00	Cubas, Philippines, Porto Ricos.
" 13...........	3.46	69.20	Cubas.
" 14...........	3.49	69.80	Cubas, 3.48, 3.50; Porto Ricos, 3.49, 3.50; Philippines, 3.50.
" 16...........	3.50	70.00	Porto Ricos, Cubas.
" 20...........	3.55	71.00	Cubas.
" 28...........	3.545	70.90	Cubas, 3.55; Porto Ricos, 3.54.
" 29...........	3.50	70.00	Cubas.
Aug. 5...........	3.51	70.20	Porto Ricos.
" 10...........	3.50	70.00	St. Croix.
" 17...........	3.47	69.40	Cubas.
" 21...........	3.415	68.30	Cubas, 3.41, 3.42.
" 24...........	3.39	67.80	Cubas, 3.38, 3.40; Porto Ricos, 3.40.
" 25...........	3.42	68.40	Cubas.
" 27...........	3.39	67.80	Cubas, 3.38, 3.40.
" 28...........	3.40	68.00	Porto Ricos.
" 31...........	3.38	67.60	Cubas.
Sept. 2...........	3.375	67.50	Cubas, 3.37, 3.38.
" 3...........	3.37	67.40	Philippines, Porto Ricos.
" 4...........	3.40	68.00	Cubas.
" 9...........	3.42	68.40	Cubas, Porto Ricos.
" 10...........	3.45	69.00	Cubas.
" 11...........	3.445	68.90	Cubas, 3.44, 3.45; Philippines, 3.45.
" 14...........	3.44	68.80	Cubas.